Threats to Biodiversity in Saskatchewan

by

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Plant Ecology Section

Environment Branch

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EXECUTIVE SUMMARY

Threats to biodiversity in Saskatchewan are listed and categorized. Spatial extent within the province's 11 ecoregions are rated on a three-point scale, and occurrence within watersheds is listed for aquatic threats. The severity of each threat where it occurs is also rated on a three-point scale. The overall degree of threat is assessed, based on the combination of ratings for extent and severity. The largest overall threats are in the categories of habitat loss and alteration (both terrestrial and aquatic), habitat fragmentation (both terrestrial and aquatic), invasion of exotic species (terrestrial), and pollution (aquatic). Policy recommendations are provided to address the major causes of these threats: climate change, clearing and breaking for agriculture, wetland drainage, roads, dams, urban/industrial development, pesticide use, and introduction of exotic species. Notes on each threat are provided, based on a preliminary literature review as well as interviews with provincial government staff as well as other experts outside of government.

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1. ANALYSIS OF THREATS TO BIODIVERSITY

1.1 Introduction

Saskatchewan Research Council was asked by SERM to review the threats to biodiversity in Saskatchewan. The first step was to list potential threats to biodiversity in Saskatchewan, based on prior work by SERM staff and on the ideas of the authors. The next step was to assess the significance of each of these threats in various parts of the province. Available information was reviewed and expert advice was sought to answer the following questions:

- is our list of potential threats complete?
- for each threat, how extensively does it occur in each ecoregion (or in watersheds for aquatic threats)?
- where it does occur, how severe are its effects on biodiversity?

The scope of the project did not allow for a detailed literature review on each of the threats, and in any case there is little scientific literature available for most of them in a Saskatchewan context. Instead, the approach that was taken was to develop enough understanding of the nature of the threat to provide general answers to the above questions. These answers are based on the understanding and judgment of the authors and not on quantitative analysis, for which the data and methods do not yet exist. Others may disagree with the ratings given or better information may be found, but the process followed can be easily modified if ratings are changed. Notes on each of the threats are given in Section 2 of the report.

1.2 Threats database

Threats were separated between those affecting **terrestrial** and **aquatic** biodiversity, and were arranged in a spreadsheet database with the following fields:

Potential threat, including human activities responsible where appropriate

Type of threat, using the following categories. The nature of these categories is discussed in Section 2.1.

- Habitat loss and alteration
- Fragmentation
- Exotic invasion
- Pollution
- Overharvesting
- Loss of genetic diversity

Extent by Saskatchewan ecoregion (Map 1). Ecoregion abbreviations are as follows:

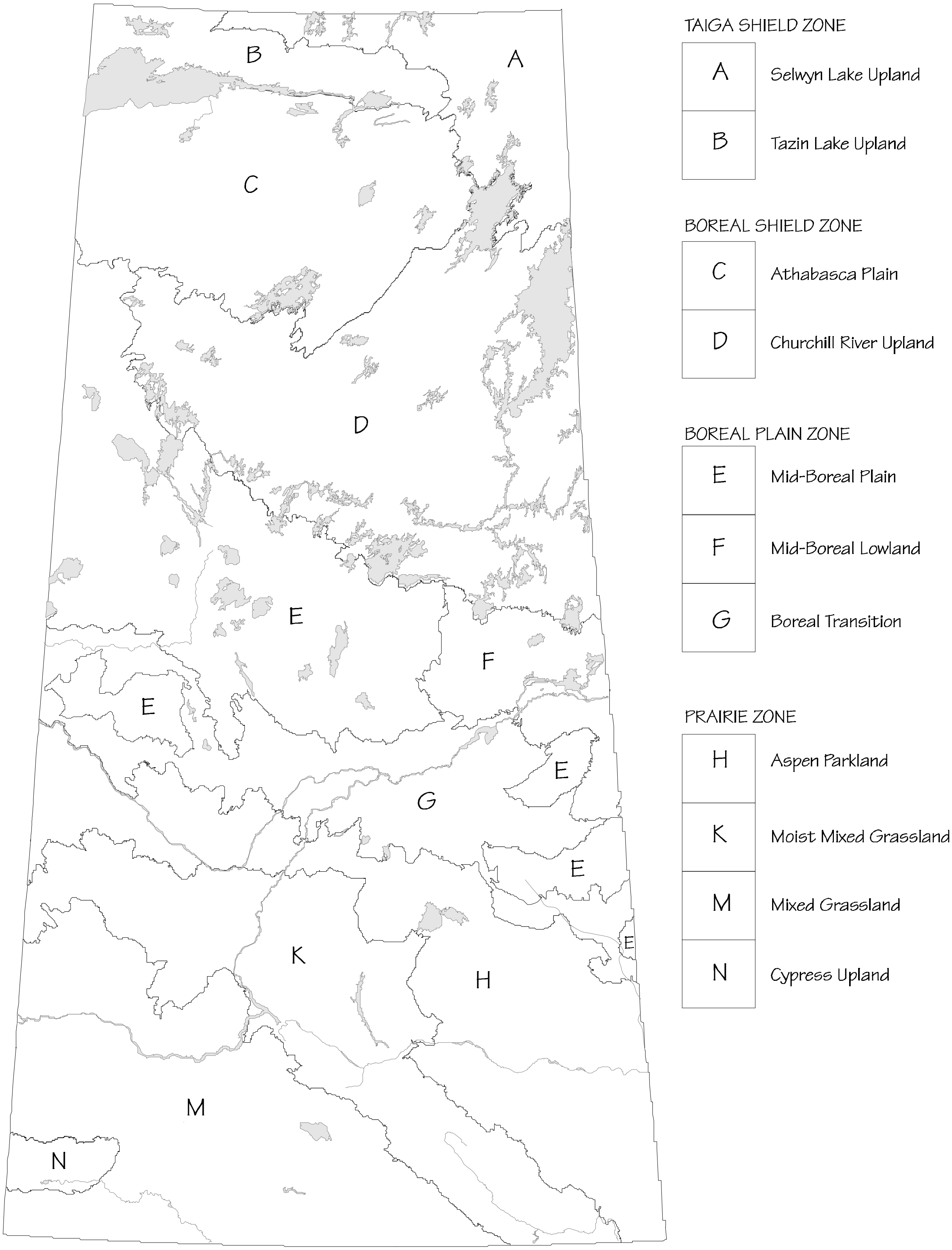
CU	Cypress Upland
MG	Mixed Grassland
MMG	Moist Mixed Grassland
AP	Aspen Parkland
BT	Boreal Transition
MBU	Mid-boreal Upland

MBL	Mid-boreal Lowland
CRU	Churchill River Upland
ATP	Athabasca Plain
TLU	Tazin Lake Upland
SLU	Selwyn Lake Upland

Extent is indicated as follows.

SYMBOL	MEANING
+++	Extensive (i.e. covering significant, measurable areas within the ecoregion)
++	Frequently scattered (i.e. not covering a large area, but occurring at many locations through the ecoregion)
+	Isolated locations (i.e. occurring at only a few locations in the ecoregion)

Terrestrial Ecoregions of Saskatchewan



Map 1

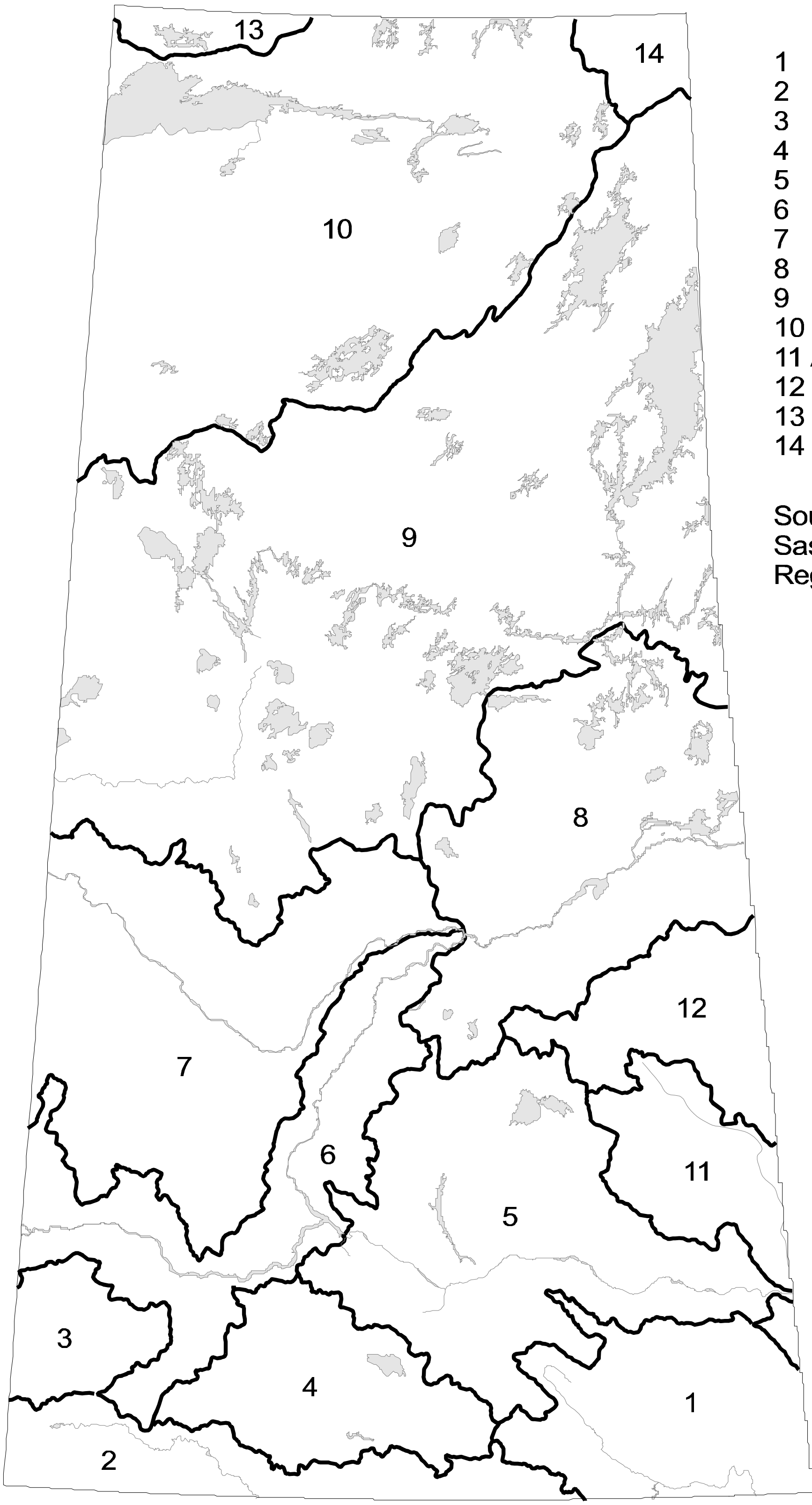
Drainage basin, using the SaskWater classification of drainage basins, for threats affecting aquatic biodiversity (see Map 2; numerical codes for sub-basins are given in Appendix A). Because of inadequate information, no attempt was made to rate the extent within drainage basins.

Severity of the threat where it does occur, using the following scale:

SYMBOL	MEANING
xxx	Severe
xx	Moderately severe
x	Moderate

No exact definitions of these ratings have been attempted, because we do not have the information to apply a truly quantitative scale (e.g. percentage of the total genetic diversity in a region lost). In the context of habitat loss and alteration, our concept of "severe" applies to complete destruction of a habitat and loss of most of its native biodiversity, whereas our concept of "moderate" applies to lesser habitat changes which still leave a largely native ecosystem with most of its biodiversity. Complete habitat loss is considered severe not just because of the individual species affected, but also because native ecosystems are themselves a critical component of Saskatchewan's biodiversity. For other categories of threats, we tried to assign ratings by comparison to the habitat loss/alteration scale, taking into account factors such as temporary versus permanent impacts, effects on rare versus common species, and so on. However, it must be recognized that this was a subjective process.

Drainage Basins of Saskatchewan
SaskWater Format



1 Souris River
2 Missouri River
3 Cypress Hills (North Slope)
4 Old Wives Lake
5 Qu'Appelle River
6 South Saskatchewan River
7 North Saskatchewan River
8 Saskatchewan River
9 Churchill River
10 Lake Athabasca
11 Assiniboine River
12 Lake Winnipegosis
13 Tazin River
14 Kasba Lake

Source:
SaskWater 1:1,000,000
Registrar's Management Map.

Map 2

Overall threat index by ecoregion. This was based on combinations of the extent and severity ratings. The resulting scale is:

EXTENT/SEVERITY SYMBOLS	OVERALL THREAT SYMBOL	MEANING
+++ / xxx	#####	Extensive/Severe
++ / xxx or +++ / xx	####	Frequently Scattered/Severe or Extensive/Moderately Severe
+ / xxx or ++ / xx or +++ / x	###	Isolated/Severe or Frequently scattered/Moderately Severe or Extensive/Moderate
+ / xx or ++ / x	##	Isolated/Moderately Severe or Frequently scattered/Moderate
+ / x	#	Isolated/Moderate

Timing of the threat. For certain threats, the following labels are shown:

F	Indicates that the threat is mainly in the **future**, so is accompanied by some uncertainty.
P	Indicates that most of the action causing the threat occurred in the **past** (i.e. most of the damage is already done), although it could be continuing in the present.

Confidence in our ratings for extent and severity, based on the amount of information available and our perceived level of understanding of the nature of the threat:

1	lower level of confidence
2	higher level of confidence

Table 1 represents the spreadsheet for threats to terrestrial biodiversity, in a somewhat condensed form. Table 2 shows the same information for threats to aquatic biodiversity.

1.3 Patterns of threats

The spreadsheet database was sorted to summarize the threats within each ecoregion (Tables 3a through 3k). Threats are organized so as to show the highest overall levels first. These tables show which threats cause most concern in each ecoregion.

Table 1 Database of potential threats to terrestrial biodiversity

POTENTIAL THREAT	EXTENT BY ECOREGION											SEVERITY	TIME	CONF.
	CU	MG	MMG	AP	BT	MBU	MBL	CRU	ATP	TLU	SLU			
HABITAT LOSS AND ALTERATION														
Shifts in ecoregions due to climatic change	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	xxx in CH to BT; xx in MBU to SLU	F	1
Changes in forest age-class distribution due to timber harvesting	++				++	+++	+++	+++				x		2
Habitat changes in clearcuts compared to burns	++				++	+++	+++	+++				x		1
Changes in forest due to fire suppression	+++				+++	+++	+++	+++				x		2
Loss of burn habitats due to fire salvage					++	+++	+++	+++				x		1
Changes in grasslands due to fire suppression	+++	+++	+++	+++								x, except xx in AP		1
Habitat loss due to clearing/breaking for agriculture	+++	+++	+++	+++	+++							xxx	P	2
Changes in range condition and habitat due to livestock grazing	+++	+++	+++	+++	+++	++	++					x		2
Damage to riparian vegetation by livestock grazing	+++	+++	+++	+++	+++	++	++					x		2
Flooding of riparian ecosystems due to dam construction	++	+++	+++	++	+++	?	?	+		+		xxx		2
Changes in riparian habitats downstream from dams	++	+++	+++	++	+++		+++	+		+		xx		2
Habitat loss due to road construction	+++	+++	+++	+++	+++	++	++	+	+	+		xxx		2
Habitat loss due to other linear developments	++	++	++	++	++	+	+	+	+	+		x		1
Habitat loss due to urban/industrial development	+	++	++	++	++	+	+	+	+	+		xxx		2
Habitat loss due to coal mining		+	+									xxx		2
Disturbance of ecosystems due to recreation traffic	++	++	++	++	++	++	++					x		1
Disturbance of ecosystems due to military activities			+			+						xx		2
Effect on migratory spp. of habitat loss outside of Sask.	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	xx		1
HABITAT FRAGMENTATION														
Fragmentation due to timber harvesting	++				++	+++	+++	+++				x		2
Fragmentation due to clearing/breaking for agriculture	+++	+++	+++	+++	+++							xxx	P	2
Fragmentation due to road construction	+++	+++	+++	+++	+++	++	++	+	+	+		xx		1
Fragmentation due to other linear developments	++	++	++	++	++	+	+	+	+	+		x		1

POTENTIAL THREAT	EXTENT BY ECOREGION											SEVERITY	TIME	CONF.
	CU	MG	MMG	AP	BT	MBU	MBL	CRU	ATP	TLU	SLU			
EXOTIC INVASION														
Invasion of upland vegetation by exotic plants	++	+++	+++	+++	+++	+	+					xx, except xxx in MMG and AP		2
Invasion of exotic birds	++	+++	+++	+++	+++							x		2
Invasion of exotic insects	+++	+++	+++	+++	+++	?	?	?	?	?	?	xx		1
Invasion of exotic microbe pests	?	?	?	?	?	?	?	?	?	?	?	?		1
Predation by domestic cats and dogs	++	+++	+++	+++	++							x		1
Dispersal of exotics due to clearing/breaking for agriculture	+++	+++	+++	+++	+++							xx	P	2
Spread of disease from livestock operations and game farms	+	+	+	+	+							x		1
Dispersal of exotics due to road construction	+++	+++	+++	+++	+++	+	+	+	+	+		xx		2
Dispersal of exotics due to other linear developments	++	++	++	++	++							x		1
POLLUTION														
Vegetation damage due to acid precipitation								++	++	++	++	x	F	2
Pollution due to oil/gas extraction	+	+	+	+	+	+						x		1
Vegetation damage due to potash mines			+	+								x		2
Vegetation damage due to other industry		+	+	+	+							?		1
Air pollution due to greenhouse gases	+	++	++	++	++							?		1
Poisoning of non-target wildlife due to pesticide use	+++	+++	+++	+++	+++	+	+					xx		1
Loss of migratory birds due to pesticide use outside of Sask.	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	xx		1
OVERHARVESTING														
Overharvesting of big game						+	+	+	+			xx		1
Overharvesting of medicinal and other plants			+	+	+							x		1
LOSS OF GENETIC DIVERSITY														
Loss of diversity in planted tree seedlings	++				++	+++	+++	+++				x		2
Loss of diversity in crop plants	+++	+++	+++	+++	+++							xx		2
Threats of genetically engineered crops	++	++	++	++	++							?		1

Table 2 Database of potential threats to aquatic biodiversity

POTENTIAL THREAT	EXTENT BY ECOREGION											DRAINAGE BASINS	SEV	TIME	CONF.
	CU	MG	MMG	AP	BT	MBU	MBL	CRU	ATP	TLU	SLU				
HABITAT LOSS AND ALTERATION															
Shifts in ecoregions due to climatic change	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	1.2345678910e+18	xxx in CH to BT; xx in MBU to SLU	F	1
Drainage of wetlands	?	+++	+++	+++	+++							1,5,6,7,8,11,12,	xxx		2
Downstream effects of drainage of wetlands		?	++	++	?							5,11,others?	x		1
Change in aquatic habitats due to channelization	?	?	++	++	?							5, others?	xx		1
Change from stream to reservoir due to dam construction	++	+++	+++	++	+++	?	?	+		+		1,2,3,4,5,6,7, 8,9,11,12,13	xxx		2
Changes in aquatic habitats downstream from dams	++	+++	+++	++	+++		+++	+		+		1,2,3,4,5,6,7, 8,9,11,12,13	xx		2
Downstream effects of irrigation	?	?	?	?	?							?	?	F	1
Change in lake levels and river flows due to water diversion	?	++	++	++	?	?	?					4,5,others?	xx	F	2
Disturbance of ecosystems due to recreation traffic	++	++	++	++	++	++	++					1,2,3,4,5,6,7, 8,9,11,12	x		1
HABITAT FRAGMENTATION															
Barriers to dispersal due to dam construction	++	+++	+++	++	+++			+		+		1,2,3,4,5,6,7, 8,9,11,12,13	xxx		2
Barriers to dispersal due to road construction	+++	+++	+++	+++	+++	++	++	+	+	+		1,2,3,4,5,6,7, 8,9	xx		1
EXOTIC INVASION															
Invasion of wetlands by exotic plants	?	+	+	+	+	+	+	+	?	?	?	1,2,3,4,5,6,7, 8,9,11,12	xx		2
Invasion of exotic microbe pests	?	?	?	?	?	?	?	?	?	?	?	?	?		1
Invasion of exotic fish and molluscs		++	++	++								2,5,11	xx	F	2
Dispersal of exotics due to water diversion			+	+								5, others?	xx	F	2
POLLUTION															
Aquatic effects of acid precipitation								+++	+++	+++	+++	8(67),9,10	x	F	2
Siltation/eutrophication due to clearing/breaking for agriculture	+++	+++	+++	+++	+++							1,2,3,4,5,6,7, 8,9(61),11,12	xx	P	1

POTENTIAL THREAT	EXTENT BY ECOREGION											DRAINAGE BASINS	SEV	TIME	CONF.
	CU	MG	MMG	AP	BT	MBU	MBL	CRU	ATP	TLU	SLU				
Poisoning of non-target wildlife due to pesticide use	+++	+++	+++	+++	+++	+	+					1,2,3,4,5,6,7, 8,9,11,12	xx		1
Siltation/eutrophication due to livestock grazing	+++	+++	+++	+++	+++	++	+					1,2,3,4,5,6,7, 8,9(61),11,12	x		1
Siltation due to roads	+++	+++	+++	+++	+++	++	++	+	+	+		1,2,3,4,5,6,7, 8,9	x		1
Pollution due to oil/gas extraction	+	+	+	+	+	+						1,2,3,4,5?,6,7 ,9	x		1
Water pollution due to metals mining								+	+	+		9,10	xx		1
Water pollution due to other industry		+	+	+	+							1,2,4,5,6,7,8, 11,12	?		1
Pollution due to sewage release	+	++	++	++	++	+	+	+	+	+		1,2?,4?,5,6,7, 8,9,10,11,12, 13	x		1
Water pollution due to landfills	+	++	++	++	++	+	+	+	+	+		?	?		1
OVERHARVESTING															
Overharvesting of fish species		++	++	++	++	++	++	++				6(30),7(29),8 (67),9	xx		2

Table 3a Ranking of threats in the Cypress Upland Ecoregion

POTENTIAL THREAT	TYPE OF THREAT	EXTENT	SEVERITY	OVERALL	TIME
THREATS TO TERRESTRIAL BIODIVERSITY					
Habitat loss due to road construction	Habitat loss/alteration	+++	xxx	#####	
Fragmentation due to clearing/breaking for agriculture	Habitat fragmentation	+++	xxx	#####	P
Shifts in ecoregions due to climatic change	Habitat loss/alteration	+++	xxx	#####	F
Habitat loss due to clearing/breaking for agriculture	Habitat loss/alteration	+++	xxx	#####	P
Flooding of riparian ecosystems due to dam construction	Habitat loss/alteration	++	xxx	####	
Poisoning of non-target wildlife due to pesticide use	Pollution	+++	xx	####	
Invasion of exotic insects	Exotic invasion	+++	xx	####	
Dispersal of exotics due to clearing/breaking for agriculture	Exotic invasion	+++	xx	####	P
Fragmentation due to road construction	Habitat fragmentation	+++	xx	####	
Dispersal of exotics due to road construction	Exotic invasion	+++	xx	####	
Loss of diversity in crop plants	Loss of genetic diversity	+++	xx	####	
Habitat loss due to urban/industrial development	Habitat loss/alteration	+	xxx	###	
Changes in riparian habitats downstream from dams	Habitat loss/alteration	++	xx	###	
Invasion of upland vegetation by exotic plants	Exotic invasion	++	xx	###	
Changes in forest due to fire suppression	Habitat loss/alteration	+++	x	###	
Changes in grasslands due to fire suppression	Habitat loss/alteration	+++	x	###	
Changes in range condition and habitat due to livestock grazing	Habitat loss/alteration	+++	x	###	
Damage to riparian vegetation by livestock grazing	Habitat loss/alteration	+++	x	###	
Fragmentation due to other linear developments	Habitat fragmentation	++	x	##	
Disturbance of ecosystems due to recreation traffic	Habitat loss/alteration	++	x	##	
Dispersal of exotics due to other linear developments	Exotic invasion	++	x	##	
Invasion of exotic birds	Exotic invasion	++	x	##	
Fragmentation due to timber harvesting	Habitat fragmentation	++	x	##	
Changes in forest age-class distribution due to timber harvesting	Habitat loss/alteration	++	x	##	
Habitat changes in clearcuts compared to burns	Habitat loss/alteration	++	x	##	
Predation by domestic cats and dogs	Exotic invasion	++	x	##	
Habitat loss due to other linear developments	Habitat loss/alteration	++	x	##	
Loss of diversity in planted tree seedlings	Loss of genetic diversity	++	x	##	
Pollution due to oil/gas extraction	Pollution	+	x	#	
Spread of disease from livestock operations and game farms	Exotic invasion	+	x	#	
THREATS TO AQUATIC BIODIVERSITY					
Shifts in ecoregions due to climatic change	Habitat loss/alteration	+++	xxx	#####	F
Barriers to dispersal due to dam construction	Fragmentation	++	xxx	####	
Change from stream to reservoir due to dam construction	Habitat loss/alteration	++	xxx	####	
Barriers to dispersal due to road construction	Fragmentation	+++	xx	####	
Siltation/eutrophication due to clearing/breaking for agriculture	Pollution	+++	xx	####	P
Poisoning of non-target wildlife due to pesticide use	Pollution	+++	xx	####	
Changes in aquatic habitats downstream from dams	Habitat loss/alteration	++	xx	###	
Siltation due to roads	Pollution	+++	x	###	
Siltation/eutrophication due to livestock grazing	Pollution	+++	x	###	
Disturbance of ecosystems due to recreation traffic	Habitat loss/alteration	++	x	##	
Pollution due to oil/gas extraction	Pollution	+	x	#	
Pollution due to sewage release	Pollution	+	x	#	

Table 3b Ranking of threats in the Mixed Grassland Ecoregion

POTENTIAL THREAT	TYPE OF THREAT	EXTENT	SEVERITY	OVERALL	TIME
THREATS TO TERRESTRIAL BIODIVERSITY					
Habitat loss due to clearing/breaking for agriculture	Habitat loss/alteration	+++	xxx	#####	P
Shifts in ecoregions due to climatic change	Habitat loss/alteration	+++	xxx	#####	F
Fragmentation due to clearing/breaking for agriculture	Habitat fragmentation	+++	xxx	#####	P
Habitat loss due to road construction	Habitat loss/alteration	+++	xxx	#####	
Flooding of riparian ecosystems due to dam construction	Habitat loss/alteration	+++	xxx	#####	
Habitat loss due to urban/industrial development	Habitat loss/alteration	++	xxx	####	
Poisoning of non-target wildlife due to pesticide use	Pollution	+++	xx	####	
Changes in riparian habitats downstream from dams	Habitat loss/alteration	+++	xx	####	
Dispersal of exotics due to clearing/breaking for agriculture	Exotic invasion	+++	xx	####	P
Invasion of exotic insects	Exotic invasion	+++	xx	####	
Loss of diversity in crop plants	Loss of genetic diversity	+++	xx	####	
Invasion of upland vegetation by exotic plants	Exotic invasion	+++	xx	####	
Fragmentation due to road construction	Habitat fragmentation	+++	xx	####	
Dispersal of exotics due to road construction	Exotic invasion	+++	xx	####	
Habitat loss due to coal mining	Habitat loss/alteration	+	xxx	###	
Predation by domestic cats and dogs	Exotic invasion	+++	x	###	
Invasion of exotic birds	Exotic invasion	+++	x	###	
Damage to riparian vegetation by livestock grazing	Habitat loss/alteration	+++	x	###	
Changes in grasslands due to fire suppression	Habitat loss/alteration	+++	x	###	
Changes in range condition and habitat due to livestock grazing	Habitat loss/alteration	+++	x	###	
Disturbance of ecosystems due to recreation traffic	Habitat loss/alteration	++	x	##	
Fragmentation due to other linear developments	Habitat fragmentation	++	x	##	
Habitat loss due to other linear developments	Habitat loss/alteration	++	x	##	
Dispersal of exotics due to other linear developments	Exotic invasion	++	x	##	
Pollution due to oil/gas extraction	Pollution	+	x	#	
Spread of disease from livestock operations and game farms	Exotic invasion	+	x	#	
THREATS TO AQUATIC BIODIVERSITY					
Change from stream to reservoir due to dam construction	Habitat loss/alteration	+++	xxx	#####	
Barriers to dispersal due to dam construction	Fragmentation	+++	xxx	#####	
Shifts in ecoregions due to climatic change	Habitat loss/alteration	+++	xxx	#####	F
Drainage of wetlands	Habitat loss/alteration	+++	xxx	#####	
Changes in aquatic habitats downstream from dams	Habitat loss/alteration	+++	xx	####	
Siltation/eutrophication due to clearing/breaking for agriculture	Pollution	+++	xx	####	P
Barriers to dispersal due to road construction	Fragmentation	+++	xx	####	
Poisoning of non-target wildlife due to pesticide use	Pollution	+++	xx	####	
Overharvesting of fish species	Overharvesting	++	xx	###	
Change in lake levels and river flows due to water diversion	Habitat loss/alteration	++	xx	###	F
Invasion of exotic fish and molluscs	Exotic invasion	++	xx	###	F
Siltation/eutrophication due to livestock grazing	Pollution	+++	x	###	
Siltation due to roads	Pollution	+++	x	###	
Invasion of wetlands by exotic plants	Exotic invasion	+	xx	##	
Pollution due to sewage release	Pollution	++	x	##	
Disturbance of ecosystems due to recreation traffic	Habitat loss/alteration	++	x	##	
Pollution due to oil/gas extraction	Pollution	+	x	#	

Table 3c Ranking threats in the Moist Mixed Grassland Ecoregion

POTENTIAL THREAT	TYPE OF THREAT	EXTENT	SEVERITY	OVERALL
THREATS TO TERRESTRIAL BIODIVERSITY				
Flooding of riparian ecosystems due to dam construction	Habitat loss/alteration	+++	xxx	#####
Fragmentation due to clearing/breaking for agriculture	Habitat fragmentation	+++	xxx	#####
Habitat loss due to road construction	Habitat loss/alteration	+++	xxx	#####
Invasion of upland vegetation by exotic plants	Exotic invasion	+++	xxx	#####
Shifts in ecoregions due to climatic change	Habitat loss/alteration	+++	xxx	#####
Habitat loss due to clearing/breaking for agriculture	Habitat loss/alteration	+++	xxx	#####
Habitat loss due to urban/industrial development	Habitat loss/alteration	++	xxx	####
Loss of diversity in crop plants	Loss of genetic diversity	+++	xx	####
Invasion of exotic insects	Exotic invasion	+++	xx	####
Changes in riparian habitats downstream from dams	Habitat loss/alteration	+++	xx	####
Poisoning of non-target wildlife due to pesticide use	Pollution	+++	xx	####
Dispersal of exotics due to road construction	Exotic invasion	+++	xx	####
Dispersal of exotics due to clearing/breaking for agriculture	Exotic invasion	+++	xx	####
Fragmentation due to road construction	Habitat fragmentation	+++	xx	####
Habitat loss due to coal mining	Habitat loss/alteration	+	xxx	###
Predation by domestic cats and dogs	Exotic invasion	+++	x	###
Damage to riparian vegetation by livestock grazing	Habitat loss/alteration	+++	x	###
Changes in range condition and habitat due to livestock grazing	Habitat loss/alteration	+++	x	###
Changes in grasslands due to fire suppression	Habitat loss/alteration	+++	x	###
Invasion of exotic birds	Exotic invasion	+++	x	###
Disturbance of ecosystems due to military activities	Habitat loss/alteration	+	xx	##
Dispersal of exotics due to other linear developments	Exotic invasion	++	x	##
Habitat loss due to other linear developments	Habitat loss/alteration	++	x	##
Disturbance of ecosystems due to recreation traffic	Habitat loss/alteration	++	x	##
Fragmentation due to other linear developments	Habitat fragmentation	++	x	##
Pollution due to oil/gas extraction	Pollution	+	x	#
Vegetation damage due to potash mines	Pollution	+	x	#
Overharvesting of medicinal and other plants	Overharvesting	+	x	#
Spread of disease from livestock operations and game farms	Exotic invasion	+	x	#
THREATS TO AQUATIC BIODIVERSITY				
Shifts in ecoregions due to climatic change	Habitat loss/alteration	+++	xxx	#####
Barriers to dispersal due to dam construction	Fragmentation	+++	xxx	#####
Drainage of wetlands	Habitat loss/alteration	+++	xxx	#####
Change from stream to reservoir due to dam construction	Habitat loss/alteration	+++	xxx	#####
Poisoning of non-target wildlife due to pesticide use	Pollution	+++	xx	####
Siltation/eutrophication due to clearing/breaking for agriculture	Pollution	+++	xx	####
Barriers to dispersal due to road construction	Fragmentation	+++	xx	####
Changes in aquatic habitats downstream from dams	Habitat loss/alteration	+++	xx	####
Overharvesting of fish species	Overharvesting	++	xx	###
Invasion of exotic fish and molluscs	Exotic invasion	++	xx	###
Change in lake levels and river flows due to water diversion	Habitat loss/alteration	++	xx	###
Change in aquatic habitats due to channelization	Habitat loss/alteration	++	xx	###
Siltation/eutrophication due to livestock grazing	Pollution	+++	x	###
Siltation due to roads	Pollution	+++	x	###
Invasion of wetlands by exotic plants	Exotic invasion	+	xx	##

POTENTIAL THREAT	TYPE OF THREAT	EXTENT	SEVERITY	OVERALL
Dispersal of exotics due to water diversion	Exotic invasion	+	xx	##
Pollution due to sewage release	Pollution	++	x	##
Downstream effects of drainage of wetlands	Habitat loss/alteration	++	x	##
Disturbance of ecosystems due to recreation traffic	Habitat loss/alteration	++	x	##
Pollution due to oil/gas extraction	Pollution	+	x	#

Table 3d Ranking of threats in the Aspen Parkland Ecoregion

POTENTIAL THREAT	TYPE OF THREAT	EXTENT	SEVERITY	OVERALL	TIME
THREATS TO TERRESTRIAL BIODIVERSITY					
Shifts in ecoregions due to climatic change	Habitat loss/alteration	+++	xxx	#####	F
Habitat loss due to road construction	Habitat loss/alteration	+++	xxx	#####	
Invasion of upland vegetation by exotic plants	Exotic invasion	+++	xxx	#####	
Fragmentation due to clearing/breaking for agriculture	Habitat fragmentation	+++	xxx	#####	P
Habitat loss due to clearing/breaking for agriculture	Habitat loss/alteration	+++	xxx	#####	P
Habitat loss due to urban/industrial development	Habitat loss/alteration	++	xxx	####	
Fragmentation due to road construction	Habitat fragmentation	+++	xx	####	
Changes in grasslands due to fire suppression	Habitat loss/alteration	+++	xx	####	
Poisoning of non-target wildlife due to pesticide use	Pollution	+++	xx	####	
Loss of diversity in crop plants	Loss of genetic diversity	+++	xx	####	
Invasion of exotic insects	Exotic invasion	+++	xx	####	
Dispersal of exotics due to road construction	Exotic invasion	+++	xx	####	
Dispersal of exotics due to clearing/breaking for agriculture	Exotic invasion	+++	xx	####	P
Flooding of riparian ecosystems due to dam construction	Habitat loss/alteration	++	xxx	####	
Predation by domestic cats and dogs	Exotic invasion	+++	x	###	
Damage to riparian vegetation by livestock grazing	Habitat loss/alteration	+++	x	###	
Invasion of exotic birds	Exotic invasion	+++	x	###	
Changes in range condition and habitat due to livestock grazing	Habitat loss/alteration	+++	x	###	
Changes in riparian habitats downstream from dams	Habitat loss/alteration	++	xx	###	
Disturbance of ecosystems due to recreation traffic	Habitat loss/alteration	++	x	##	
Habitat loss due to other linear developments	Habitat loss/alteration	++	x	##	
Fragmentation due to other linear developments	Habitat fragmentation	++	x	##	
Dispersal of exotics due to other linear developments	Exotic invasion	++	x	##	
Pollution due to oil/gas extraction	Pollution	+	x	#	
Vegetation damage due to potash mines	Pollution	+	x	#	
Overharvesting of medicinal and other plants	Overharvesting	+	x	#	
Spread of disease from livestock operations and game farms	Exotic invasion	+	x	#	
THREATS TO AQUATIC BIODIVERSITY					
Drainage of wetlands	Habitat loss/alteration	+++	xxx	#####	
Shifts in ecoregions due to climatic change	Habitat loss/alteration	+++	xxx	#####	F
Poisoning of non-target wildlife due to pesticide use	Pollution	+++	xx	####	
Siltation/eutrophication due to clearing/breaking for agriculture	Pollution	+++	xx	####	P
Barriers to dispersal due to road construction	Fragmentation	+++	xx	####	
Barriers to dispersal due to dam construction	Fragmentation	++	xxx	####	
Change from stream to reservoir due to dam construction	Habitat loss/alteration	++	xxx	####	
Change in lake levels and river flows due to water diversion	Habitat loss/alteration	++	xx	###	F
Invasion of exotic fish and molluscs	Exotic invasion	++	xx	###	F

POTENTIAL THREAT	TYPE OF THREAT	EXTENT	SEVERITY	OVERALL	TIME
Change in aquatic habitats due to channelization	Habitat loss/alteration	++	xx	###	
Overharvesting of fish species	Overharvesting	++	xx	###	
Siltation/eutrophication due to livestock grazing	Pollution	+++	x	###	
Siltation due to roads	Pollution	+++	x	###	
Changes in aquatic habitats downstream from dams	Habitat loss/alteration	++	xx	###	
Invasion of wetlands by exotic plants	Exotic invasion	+	xx	##	
Dispersal of exotics due to water diversion	Exotic invasion	+	xx	##	F
Downstream effects of drainage of wetlands	Habitat loss/alteration	++	x	##	
Pollution due to sewage release	Pollution	++	x	##	
Disturbance of ecosystems due to recreation traffic	Habitat loss/alteration	++	x	##	
Pollution due to oil/gas extraction	Pollution	+	x	#	

Table 3e Ranking of threats in the Boreal Transition Ecoregion

POTENTIAL THREAT	TYPE OF THREAT	EXTENT	SEVERITY	OVERALL	TIME
THREATS TO TERRESTRIAL BIODIVERSITY					
Habitat loss due to road construction	Habitat loss/alteration	+++	xxx	#####	
Shifts in ecoregions due to climatic change	Habitat loss/alteration	+++	xxx	#####	F
Fragmentation due to clearing/breaking for agriculture	Habitat fragmentation	+++	xxx	#####	P
Habitat loss due to clearing/breaking for agriculture	Habitat loss/alteration	+++	xxx	#####	P
Flooding of riparian ecosystems due to dam construction	Habitat loss/alteration	+++	xxx	#####	
Habitat loss due to urban/industrial development	Habitat loss/alteration	++	xxx	####	
Invasion of exotic insects	Exotic invasion	+++	xx	####	
Dispersal of exotics due to clearing/breaking for agriculture	Exotic invasion	+++	xx	####	P
Changes in riparian habitats downstream from dams	Habitat loss/alteration	+++	xx	####	
Poisoning of non-target wildlife due to pesticide use	Pollution	+++	xx	####	
Invasion of upland vegetation by exotic plants	Exotic invasion	+++	xx	####	
Fragmentation due to road construction	Habitat fragmentation	+++	xx	####	
Dispersal of exotics due to road construction	Exotic invasion	+++	xx	####	
Loss of diversity in crop plants	Loss of genetic diversity	+++	xx	####	
Invasion of exotic birds	Exotic invasion	+++	x	###	
Changes in range condition and habitat due to livestock grazing	Habitat loss/alteration	+++	x	###	
Changes in forest due to fire suppression	Habitat loss/alteration	+++	x	###	
Damage to riparian vegetation by livestock grazing	Habitat loss/alteration	+++	x	###	
Disturbance of ecosystems due to recreation traffic	Habitat loss/alteration	++	x	##	
Fragmentation due to other linear developments	Habitat fragmentation	++	x	##	
Loss of burn habitats due to fire salvage	Habitat loss/alteration	++	x	##	
Changes in forest age-class distribution due to timber harvesting	Habitat loss/alteration	++	x	##	
Fragmentation due to timber harvesting	Habitat fragmentation	++	x	##	
Habitat loss due to other linear developments	Habitat loss/alteration	++	x	##	
Loss of diversity in planted tree seedlings	Loss of genetic diversity	++	x	##	
Habitat changes in clearcuts compared to burns	Habitat loss/alteration	++	x	##	
Dispersal of exotics due to other linear developments	Exotic invasion	++	x	##	
Predation by domestic cats and dogs	Exotic invasion	++	x	##	
Pollution due to oil/gas extraction	Pollution	+	x	#	
Spread of disease from livestock operations and game farms	Exotic invasion	+	x	#	
Overharvesting of medicinal and other plants	Overharvesting	+	x	#	
THREATS TO AQUATIC BIODIVERSITY					
Change from stream to reservoir due to dam construction	Habitat loss/alteration	+++	xxx	#####	
Barriers to dispersal due to dam construction	Fragmentation	+++	xxx	#####	
Drainage of wetlands	Habitat loss/alteration	+++	xxx	#####	

POTENTIAL THREAT	TYPE OF THREAT	EXTENT	SEVERITY	OVERALL	TIME
Shifts in ecoregions due to climatic change	Habitat loss/alteration	+++	xx	#####	F
Changes in aquatic habitats downstream from dams	Habitat loss/alteration	+++	xx	####	
Siltation/eutrophication due to clearing/breaking for agriculture	Pollution	+++	xx	####	P
Poisoning of non-target wildlife due to pesticide use	Pollution	+++	xx	####	
Barriers to dispersal due to road construction	Fragmentation	+++	xx	####	
Overharvesting of fish species	Overharvesting	++	xx	###	
Siltation due to roads	Pollution	+++	x	###	
Siltation/eutrophication due to livestock grazing	Pollution	+++	x	###	
Invasion of wetlands by exotic plants	Exotic invasion	+	xx	##	
Disturbance of ecosystems due to recreation traffic	Habitat loss/alteration	++	x	##	
Pollution due to sewage release	Pollution	++	x	##	
Pollution due to oil/gas extraction	Pollution	+	x	#	

Table 3f Ranking of threats in the Mid-Boreal Upland Ecoregion

POTENTIAL THREAT	TYPE OF THREAT	EXTENT	SEVERITY	OVERALL	TIME
THREATS TO TERRESTRIAL BIODIVERSITY					
Habitat loss due to road construction	Habitat loss/alteration	++	xxx	####	
Shifts in ecoregions due to climatic change	Habitat loss/alteration	+++	xx	####	F
Habitat loss due to urban/industrial development	Habitat loss/alteration	+	xxx	###	
Fragmentation due to road construction	Habitat fragmentation	++	xx	###	
Loss of burn habitats due to fire salvage	Habitat loss/alteration	+++	x	###	
Fragmentation due to timber harvesting	Habitat fragmentation	+++	x	###	
Habitat changes in clearcuts compared to burns	Habitat loss/alteration	+++	x	###	
Changes in forest due to fire suppression	Habitat loss/alteration	+++	x	###	
Loss of diversity in planted tree seedlings	Loss of genetic diversity	+++	x	###	
Changes in forest age-class distribution due to timber harvesting	Habitat loss/alteration	+++	x	###	
Overharvesting of big game	Overharvesting	+	xx	##	
Poisoning of non-target wildlife due to pesticide use	Pollution	+	xx	##	
Disturbance of ecosystems due to military activities	Habitat loss/alteration	+	xx	##	
Dispersal of exotics due to road construction	Exotic invasion	+	xx	##	
Invasion of upland vegetation by exotic plants	Exotic invasion	+	xx	##	
Damage to riparian vegetation by livestock grazing	Habitat loss/alteration	++	x	##	
Disturbance of ecosystems due to recreation traffic	Habitat loss/alteration	++	x	##	
Changes in range condition and habitat due to livestock grazing	Habitat loss/alteration	++	x	##	
Pollution due to oil/gas extraction	Pollution	+	x	#	
Fragmentation due to other linear developments	Habitat fragmentation	+	x	#	
Habitat loss due to other linear developments	Habitat loss/alteration	+	x	#	
THREATS TO AQUATIC BIODIVERSITY					
Shifts in ecoregions due to climatic change	Habitat loss/alteration	+++	xx	####	F
Barriers to dispersal due to road construction	Fragmentation	++	xx	###	
Overharvesting of fish species	Overharvesting	++	xx	###	
Poisoning of non-target wildlife due to pesticide use	Pollution	+	xx	##	
Invasion of wetlands by exotic plants	Exotic invasion	+	xx	##	
Siltation due to roads	Pollution	++	x	##	
Disturbance of ecosystems due to recreation traffic	Habitat loss/alteration	++	x	##	
Siltation/eutrophication due to livestock grazing	Pollution	++	x	##	
Pollution due to oil/gas extraction	Pollution	+	x	#	
Pollution due to sewage release	Pollution	+	x	#	

Table 3g Ranking of threats in the Mid-Boreal Lowland Ecoregion

POTENTIAL THREAT	TYPE OF THREAT	EXTENT	SEVERITY	OVERALL	TIME
THREATS TO TERRESTRIAL BIODIVERSITY					
Habitat loss due to road construction	Habitat loss/alteration	++	xxx	####	
Shifts in ecoregions due to climatic change	Habitat loss/alteration	+++	xx	####	F
Changes in riparian habitats downstream from dams	Habitat loss/alteration	+++	xx	####	
Habitat loss due to urban/industrial development	Habitat loss/alteration	+	xxx	###	
Fragmentation due to road construction	Habitat fragmentation	++	xx	###	
Changes in forest age-class distribution due to timber harvesting	Habitat loss/alteration	+++	x	###	
Loss of burn habitats due to fire salvage	Habitat loss/alteration	+++	x	###	
Loss of diversity in planted tree seedlings	Loss of genetic diversity	+++	x	###	
Habitat changes in clearcuts compared to burns	Habitat loss/alteration	+++	x	###	
Changes in forest due to fire suppression	Habitat loss/alteration	+++	x	###	
Fragmentation due to timber harvesting	Habitat fragmentation	+++	x	###	
Dispersal of exotics due to road construction	Exotic invasion	+	xx	##	
Overharvesting of big game	Overharvesting	+	xx	##	
Poisoning of non-target wildlife due to pesticide use	Pollution	+	xx	##	
Invasion of upland vegetation by exotic plants	Exotic invasion	+	xx	##	
Disturbance of ecosystems due to recreation traffic	Habitat loss/alteration	++	x	##	
Changes in range condition and habitat due to livestock grazing	Habitat loss/alteration	++	x	##	
Damage to riparian vegetation by livestock grazing	Habitat loss/alteration	++	x	##	
Fragmentation due to other linear developments	Habitat fragmentation	+	x	#	
Habitat loss due to other linear developments	Habitat loss/alteration	+	x	#	
THREATS TO AQUATIC BIODIVERSITY					
Changes in aquatic habitats downstream from dams	Habitat loss/alteration	+++	xx	####	
Shifts in ecoregions due to climatic change	Habitat loss/alteration	+++	xx	####	F
Overharvesting of fish species	Overharvesting	++	xx	###	
Barriers to dispersal due to road construction	Fragmentation	++	xx	###	
Poisoning of non-target wildlife due to pesticide use	Pollution	+	xx	##	
Invasion of wetlands by exotic plants	Exotic invasion	+	xx	##	
Siltation due to roads	Pollution	++	x	##	
Disturbance of ecosystems due to recreation traffic	Habitat loss/alteration	++	x	##	
Siltation/eutrophication due to livestock grazing	Pollution	+	x	#	
Pollution due to sewage release	Pollution	+	x	#	

Table 3h Ranking of threats in the Churchill River Upland Ecoregion

POTENTIAL THREAT	TYPE OF THREAT	EXTENT	SEVERITY	OVERALL	TIME
THREATS TO TERRESTRIAL BIODIVERSITY					
Shifts in ecoregions due to climatic change	Habitat loss/alteration	+++	xx	####	F
Habitat loss due to urban/industrial development	Habitat loss/alteration	+	xxx	###	
Habitat loss due to road construction	Habitat loss/alteration	+	xxx	###	
Flooding of riparian ecosystems due to dam construction	Habitat loss/alteration	+	xxx	###	
Changes in forest age-class distribution due to timber harvesting	Habitat loss/alteration	+++	x	###	
Loss of burn habitats due to fire salvage	Habitat loss/alteration	+++	x	###	
Habitat changes in clearcuts compared to burns	Habitat loss/alteration	+++	x	###	
Loss of diversity in planted tree seedlings	Loss of genetic diversity	+++	x	###	
Changes in forest due to fire suppression	Habitat loss/alteration	+++	x	###	
Fragmentation due to timber harvesting	Habitat fragmentation	+++	x	###	
Changes in riparian habitats downstream from dams	Habitat loss/alteration	+	xx	##	
Dispersal of exotics due to road construction	Exotic invasion	+	xx	##	
Overharvesting of big game	Overharvesting	+	xx	##	
Fragmentation due to road construction	Habitat fragmentation	+	xx	##	
Vegetation damage due to acid precipitation	Pollution	++	x	##	F
Fragmentation due to other linear developments	Habitat fragmentation	+	x	#	
Habitat loss due to other linear developments	Habitat loss/alteration	+	x	#	
THREATS TO AQUATIC BIODIVERSITY					
Shifts in ecoregions due to climatic change	Habitat loss/alteration	+++	xx	####	F
Change from stream to reservoir due to dam construction	Habitat loss/alteration	+	xxx	###	
Barriers to dispersal due to dam construction	Fragmentation	+	xxx	###	
Overharvesting of fish species	Overharvesting	++	xx	###	
Aquatic effects of acid precipitation	Pollution	+++	x	###	F
Barriers to dispersal due to road construction	Fragmentation	+	xx	##	
Changes in aquatic habitats downstream from dams	Habitat loss/alteration	+	xx	##	
Water pollution due to metals mining	Pollution	+	xx	##	
Invasion of wetlands by exotic plants	Exotic invasion	+	xx	##	
Siltation due to roads	Pollution	+	x	#	
Pollution due to sewage release	Pollution	+	x	#	

Table 3i Ranking of threats in the Athabasca Plain Ecoregion

POTENTIAL THREAT	TYPE OF THREAT	EXTENT	SEVERITY	OVERALL	TIME
THREATS TO TERRESTRIAL BIODIVERSITY					
Shifts in ecoregions due to climatic change	Habitat loss/alteration	+++	xx	####	F
Habitat loss due to urban/industrial development	Habitat loss/alteration	+	xxx	###	
Habitat loss due to road construction	Habitat loss/alteration	+	xxx	###	
Overharvesting of big game	Overharvesting	+	xx	##	
Fragmentation due to road construction	Habitat fragmentation	+	xx	##	
Dispersal of exotics due to road construction	Exotic invasion	+	xx	##	
Vegetation damage due to acid precipitation	Pollution	++	x	##	F
Fragmentation due to other linear developments	Habitat fragmentation	+	x	#	
Habitat loss due to other linear developments	Habitat loss/alteration	+	x	#	
THREATS TO AQUATIC BIODIVERSITY					
Shifts in ecoregions due to climatic change	Habitat loss/alteration	+++	xx	####	F
Aquatic effects of acid precipitation	Pollution	+++	x	###	F
Water pollution due to metals mining	Pollution	+	xx	##	
Barriers to dispersal due to road construction	Fragmentation	+	xx	##	
Siltation due to roads	Pollution	+	x	#	
Pollution due to sewage release	Pollution	+	x	#	

Table 3j Ranking of threats in the Tazin Lake Upland Ecoregion

POTENTIAL THREAT	TYPE OF THREAT	EXTENT	SEVERITY	OVERALL	TIME
THREATS TO TERRESTRIAL BIODIVERSITY					
Shifts in ecoregions due to climatic change	Habitat loss/alteration	+++	xx	####	F
Habitat loss due to urban/industrial development	Habitat loss/alteration	+	xxx	###	
Habitat loss due to road construction	Habitat loss/alteration	+	xxx	###	
Flooding of riparian ecosystems due to dam construction	Habitat loss/alteration	+	xxx	###	
Changes in riparian habitats downstream from dams	Habitat loss/alteration	+	xx	##	
Dispersal of exotics due to road construction	Exotic invasion	+	xx	##	
Fragmentation due to road construction	Habitat fragmentation	+	xx	##	
Vegetation damage due to acid precipitation	Pollution	++	x	##	F
Fragmentation due to other linear developments	Habitat fragmentation	+	x	#	
Habitat loss due to other linear developments	Habitat loss/alteration	+	x	#	
THREATS TO AQUATIC BIODIVERSITY					
Shifts in ecoregions due to climatic change	Habitat loss/alteration	+++	xx	####	F
Change from stream to reservoir due to dam construction	Habitat loss/alteration	+	xxx	###	
Barriers to dispersal due to dam construction	Fragmentation	+	xxx	###	
Aquatic effects of acid precipitation	Pollution	+++	x	###	F
Water pollution due to metals mining	Pollution	+	xx	##	

Barriers to dispersal due to road construction	Fragmentation	+	xx	##	
Changes in aquatic habitats downstream from dams	Habitat loss/alteration	+	xx	##	
Pollution due to sewage release	Pollution	+	x	#	
Siltation due to roads	Pollution	+	x	#	

Table 3k Ranking of threats in the Selwyn Lake Upland Ecoregion

POTENTIAL THREAT	TYPE OF THREAT	EXTENT	SEVERITY	OVERALL	TIME
THREATS TO TERRESTRIAL BIODIVERSITY					
Shifts in ecoregions due to climatic change	Habitat loss/alteration	+++	xx	####	F
Vegetation damage due to acid precipitation	Pollution	++	x	##	F
THREATS TO AQUATIC BIODIVERSITY					
Shifts in ecoregions due to climatic change	Habitat loss/alteration	+++	xx	####	F
Aquatic effects of acid precipitation	Pollution	+++	x	###	F

Table 4 summarizes the information in Table 3 by tallying the number of threats in the top three levels (#####, ####, and ###), by ecoregion and type of threat. This summary shows how the number of threats varies among ecoregions, and also helps to show the overall provincial picture. First, the number of high-level threats is distinctly higher in the southernmost five ecoregions, which have the highest population density, virtually all of the agricultural impacts, and most of the roads, water developments, and other population-related impacts. The Moist Mixed Grassland appears to have the most high-level threats, although it is not separated by much from the other southern regions. The number of high-level threats is lower in the regions affected by commercial forestry (MBU, MBL, and CRU), and lower again in the sparsely populated northernmost regions.

Table 4 Numbers of high-level threats, by ecoregion and type of threat

	ECOREGION										
	CU	**MG**	**MMG**	**AP**	**BT**	**MBU**	**MBL**	**CRU**	**ATP**	**TLU**	**SLU**
TOP LEVEL (#####)											
Aquatic	1	4	4	2	4	0	0	0	0	0	0
Terrestrial	4	5	6	5	5	0	0	0	0	0	0
Aquatic + Terrestrial	5	9	10	7	9	0	0	0	0	0	0
TOP TWO LEVELS (#####, ####)											
Aquatic	6	8	8	7	8	1	2	1	1	1	1
Terrestrial	11	14	14	14	14	2	3	1	1	1	1
Aquatic + Terrestrial	17	22	22	21	22	3	5	2	2	2	2
TOP THREE LEVELS (#####, ####, ###)											
Aquatic	9	13	14	14	11	3	4	5	2	4	2
Terrestrial	18	20	20	19	18	10	11	10	3	4	1
Aquatic + Terrestrial	27	33	34	33	29	13	15	15	5	8	3

Table 5 shows the number of high-level threats falling into the various types of threat. For both aquatic and terrestrial biodiversity, the greatest number of high-level threats fell under *Habitat loss and alteration*. *Fragmentation* was relatively important in both aquatic and terrestrial sections, but *Pollution* ranked higher under the aquatic and *Exotic invasion* under the terrestrial section.

Table 5 Number of high-level threats, by type of threat

TYPE OF THREAT	TOP LEVEL (#####)	TOP TWO LEVELS (#####, ####)	TOP THREE LEVELS (#####, ####, ###)
AQUATIC			
Habitat loss/alteration	12	24	33
Pollution	0	10	24
Habitat fragmentation	3	10	14
Overharvesting	0	0	7
Exotic invasion	0	0	3
Loss of genetic diversity	0	0	0
TERRESTRIAL			
Habitat loss/alteration	18	37	79
Exotic invasion	2	19	27
Habitat fragmentation	5	10	15
Loss of genetic diversity	0	5	8
Pollution	0	5	5
Overharvesting	0	0	0

The summary in Table 5 could be criticized on the grounds that the number of high-level threats in each category depends in part on how those threats were originally classified. For example, if two related threats were combined into one in the original classification, then this would reduce the number of possible threats. This criticism does not completely invalidate Table 5, for two reasons: the classification of threats was not completely arbitrary; and the results depend not just on the number of listed threats, but also on which ones were rated as high-level, and in how many ecoregions. However, in order to address the maximum extent to which this could affect the results, we calculated the percentage of listed threats within a category which were rated as high-level (Table 6). For example, under *Terrestrial: Exotic invasion*, there were 9 threats listed, which in 11 ecoregions gives a total count of 99. There were 27 ratings in the top three levels for this category, or 27% of the total. This analysis looks at the average level of the threats in a category, independent of how many individual threats were defined.

The main result of this analysis is that *Aquatic: Habitat fragmentation* and *Aquatic: Overharvesting* rank considerably higher in Table 6 than in Table 5, implying that their lower rating in Table 5 could be influenced by the way in which threats were classified. For the terrestrial threats, there are no such remarkable differences. *Habitat loss/alteration* is clearly the highest category, in terms of both total number of high-level threats and percentage of threats which were rated as high-level.

Table 6 Percentage of threats which are rated as high-level, by type of threat

TYPE OF THREAT	TOP LEVEL (#####)	TOP TWO LEVELS (#####, ####)	TOP THREE LEVELS (#####, ####, ###)
AQUATIC			
Habitat loss/alteration	12	24	33
Pollution	0	8	20
Fragmentation	14	45	64
Overharvesting	0	0	64
Exotic invasion	0	0	7
TERRESTRIAL			
Habitat loss/alteration	9	19	40
Exotic invasion	2	19	27
Fragmentation	11	23	34
Loss of genetic diversity	0	15	24
Pollution	0	6	6
Overharvesting	0	0	0

Because drainage basins are more relevant than ecoregions to aquatic biodiversity, we attempted to list drainage basins for the various aquatic threats (Table 2). There was insufficient information to rate the extent within each basin, and in many cases even assigning basins was based on limited information. Table 7 gives the number of threats identified for each basin. The Qu'Appelle (Basin 5) has the highest numbers, followed by the Saskatchewan system (Basins 6, 7, and 8). As expected, the northernmost basins show much lower totals: Tazin River (Basin 13), Lake Athabasca (Basin 10), and Kasba Lake (Basin 14).

Table 7 Number of threats to aquatic biodiversity, by drainage basin and level of severity

	BASIN													
SEVERITY	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Severe	4	3	3	3	4	4	4	4	2	0	4	4	2	0
Severe and Moderately severe	8	8	7	8	12	9	9	9	9	2	8	7	4	1
All threats	13	13	11	13	18	14	14	14	15	4	12	10	5	1

1.4 Recommended actions

The above analysis shows that the major threats to biodiversity in Saskatchewan are in the areas of habitat loss and alteration (both aquatic and terrestrial), fragmentation (both aquatic and terrestrial), pollution (aquatic), and exotic invasion (terrestrial). Reference back to Tables 3a through 3k shows that within these categories, the most important threats relate to a few major causes. Therefore, the most effective actions will be those that address these root causes.

Climate change

- Participate in international efforts to reduce emissions of greenhouse gases and sequester carbon.

Clearing/breaking for agriculture

- Stop the sale of Crown Lands with native vegetation.
- Extend protection against clearing/breaking to all Crown Lands supporting native vegetation
- Stop the sale of undeveloped road allowances.
- On private lands, eliminate any present or future policies (e.g. tax assessment) that encourage conversion of rangeland to cultivation.
- Support rangeland grazing operations (e.g. through GAPT program) as an alternative to breaking.
- Support conversion of cropland to perennial vegetation (e.g. permanent cover program)
- Support farm woodlot operations (e.g. through FWAS program) as an alternative to clearing.
- Support conservation easement program.

Wetland drainage

- Eliminate any present or future programs that subsidize wetland drainage.
- Support extension programs related to wetlands (e.g. through SWCC, DU).
- Support conservation easement program.

Roads

- Develop policy on government-supported road development which includes as a goal the need to limit further increases in road area.
- Complete protected areas system which includes blocks of significant size throughout Saskatchewan which are off-limits to new road development (e.g. oil/gas development).
- Limit the expansion of timber and mining industries to maintain roadless areas in northern Saskatchewan.
- Increase requirements for closure and restoration of temporary roads (e.g. timber harvesting, mineral exploration).
- Develop/enforce standards for stream crossings to permit dispersal of aquatic organisms.

Dams

- Investigate status of whole watersheds with respect to dams and other biodiversity impacts.
- Stop or slow down approval of new dams.
- Investigate decommissioning of existing dams based on overall watershed review.

Urban/industrial development

- Document areas of native vegetation around urban areas to be avoided in development plans.
- Encourage zoning in rural municipalities to prevent acreage developments on native habitat.

Pesticides

- Increase testing and registration programs, including more research on ecosystem-level effects prior to registration.
- Support research into reduced pesticide use (e.g. organic farming techniques).

Exotic invasion

- Develop and enforce policies for screening for invasive potential of intentional introductions (e.g. forage plants, horticultural plants, biological control insects).
- Control the further increase of land clearing and roads, as discussed above.
- Require use of native species in seeding of disturbed areas (road ditches, pipelines, etc.) in areas of native vegetation.

Loss of diversity in crop plants

- Support seed bank program.

2 NOTES ON THREATS TO BIODIVERSITY

2.1 Introduction

This section includes notes on the various threats identified in Section 1, based on scientific literature and interviews with SERM staff and other experts. However, this should not be considered a comprehensive literature review on these topics, which was beyond the scope of the current project. Indeed, one recommendation for future work is to conduct such a detailed literature review on the threats that have been identified here.

Threats have been divided between aquatic and terrestrial, and grouped under six broad categories:

Habitat loss and alteration

Actual loss of native habitat by conversion to other land uses is obviously a severe impact, because it implies loss of most of the biodiversity on the lands affected. A review for the United States found that habitat degradation and loss is the highest-ranking category of threat to imperilled species (Wilcove et al. 1998). According to Mosquin et al. (1995), "By far the greatest impact upon Canadian biodiversity stems from the wholesale conversion of natural systems...". Lower in severity are alterations in habitat (e.g. shifts in species composition, shifts in proportions of forest age classes) which nevertheless leave a largely native ecosystem in place. There is a whole range of impacts between complete loss and minor alteration.

Habitat fragmentation

Adding to the problem of habitat loss (i.e. loss of total area of habitat) is habitat fragmentation, which is the extent to which the total area is divided into many small fragments rather than consolidated into a few large blocks. Small patches of habitat are expected to support fewer species than larger patches, analogously with oceanic islands in which it has been shown that the number of species increases with island size, although the situation in terrestrial habitats is more complicated (Noss and Cooperrider 1994). In smaller patches of habitat, the population of a given species is small and therefore more likely to be locally extirpated. Barriers, such as intervening patches of unfavourable habitat, roads, or dams on streams, may prevent recolonization from populations in other habitat patches. Habitat corridors (i.e. linear features which connect blocks of habitat) have generally been shown to benefit the movement of animals, reducing the effects of fragmentation (Beier and Noss 1998).

Exotic Invasion

Most exotic species have little effect, but a few spread rapidly and profoundly affect ecosystems (Middleton 1994). Exotic plants may come to dominate natural vegetation, crowding out most of the native plants, while exotic fish, birds, insects and probably other organisms can similarly displace native species. In an analysis of imperilled species in the United States, exotic species made up the second most important of five general classes of threats, affecting 49% of these species, with plants, birds, and fish particularly affected (Wilcove et al. 1998). In the Northern Great Plains Steppe region (which includes southern

Saskatchewan), exotic species were rated the third most important threat to areas of native vegetation (Northern Great Plains Ecoregional Conservation Team 1999).

Pollution

Air-borne and water-borne contaminants can have obvious toxic effects on organisms. Also included in this category is siltation (i.e. input of soil material) and eutrophication (i.e. input of nutrients) into water bodies. While siltation and eutrophication are natural processes, accelerated rates of these processes can greatly alter aquatic ecosystems (Mineau et al. 1994).

Overharvesting

Historically, loss of biodiversity was often caused by overharvesting by humans, as in the case of the bison and the passenger pigeon. These losses led to legal regulation of harvests of the major "crop" species such as big game, game birds, and fish, which have reduced the potential for the massive reductions of the past. However, there are still some situations in which overharvesting is affecting diversity in Saskatchewan.

Loss of genetic diversity

The greatest loss of genetic diversity occurs when an entire species is eliminated. However, even within a species, much of the natural diversity can be lost through simplification of the variety of genotypes making up the species. This is particularly a concern with species that are subject to breeding programs intended to select desired genetic traits, such as crop plants and planted trees.

2.2 Threats to Terrestrial Biodiversity

2.2.1 Habitat loss and alteration

Shifts in ecoregions due to climate change

The locations of ecoregions in Saskatchewan are determined by climatic variables such as moisture balance. Climate change which is expected because of the increase in greenhouse gases will shift the climates associated with these ecoregions northward (Wheaton et al. 1987, Hogg 1994).

The extent and rate of climate change expected will exceed the capacity of species for acclimation or genetic adaptation, so survival of species will require migration (MacIver et al. 1994). Some species may be unable to migrate fast enough to keep up with the spatial shift in ecoclimates.

Fragmentation will exacerbate this problem. For example, a park which is an island of habitat will lose species as the climate becomes unsuitable for them, but may not gain new species proportionately because of the lack of habitat connections to allow immigration. Loss of species is expected to be most severe in the grassland regions because they are most fragmented (MacIver et al. 1994). Habitat is more continuous in the forest regions which should allow more migration of species.

Upward altitudinal shifts in ecoregions are also expected with warming. Existing island habitats associated with uplands could disappear as suitable ecoclimates shift upward until there is no more land. The greatest threat to Saskatchewan biodiversity would occur in the case of the Cypress Upland Ecoregion, which contains many species not found elsewhere in the province. This ecosystem would disappear from the province if the Cypress Hills became too warm and dry to support it.

Other consequences of climate change could be increases in fire frequency and outbreaks of certain pest insects. However, these changes are considered to be mainly economic and not biodiversity threats, given that there is also a concern about the threats to biodiversity posed by suppression of natural disturbance.

Changes in forest age-class distribution due to timber harvesting

This threat represents an alteration of habitats rather than a complete loss. One of the concerns expressed about timber harvesting is that it may eliminate old stands from the landscape. A large volume of literature has shown that certain groups of bird species require old forest (Westworth and Associates 1984, Farr 1993, James 1993, Smith 1993, Telfer 1993, Welsh 1993, Westworth and Telfer 1993, Schieck and Nietfeld 1995, Kirk et al. 1996, MacKinnon 1998). Old stands have also been found to enhance diversity of small mammals (Roy et al. 1995), provide habitat for bats (Crampton and Barclay 1995), and enhance diversity of mosses, lichens, and fungi (Crites and Dale 1995). Intensive timber harvesting aimed at harvesting all stands at economic maturity would clearly reduce forest biodiversity.

Concern over this threat is moderated by two considerations:
- 20th century fire suppression has probably increased the current percentage of old stands above natural levels.
- Current forest management plans by the major timber companies have taken this concern into account, and undertake to maintain some prescribed proportion of old stands on their license areas.

However, concern over this threat could increase in the future with pressure to increase provincial timber harvests. This could lead to demand on the timber supply which would result in modifying provisions for maintenance of old growth.

Habitat changes in clearcuts compared to burns

This threat represents an alteration of habitats rather than a complete loss. Clearcutting causes obvious changes in vegetation and associated wildlife. However, it is now recognized that the natural dynamics of our forest include periodic destruction by wildfire, followed by regeneration and succession through young, mature, and old stages. Therefore, clearcutting is considered a threat to natural biodiversity mainly to the extent that it differs from the natural disturbance caused by wildfire.

Effects of clearcutting on understory vegetation diversity have generally been found to be minor (Thrasher-Haug 1997, Maynard and MacIsaac 1998). Houston et al. (1998) found that harvesting of mixedwood forest had little effect on soil microbial processes and fungal community structure. Zelmer et al. (1995) in the Prince Albert Model Forest found lower diversity of mycorrhizal fungi in clearcuts compared to mature forest, but a similar reduction was caused by burning.

Apart from biological composition, a number of studies have shown the importance of structural features such as snags and coarse woody debris in forest habitat (Stelfox et al. 1995, Lofroth 1998). Post-burn stands generally have more snags (i.e. standing dead trees) than post-clearcut stands, although these snags may be short-lived (Sulistiyowati 1998). Because of these results, the Saskatchewan forest industry is in the process of changing their harvest practices to retain more structure in clearcuts, to more closely imitate post-wildfire stands. However, Hobson and Schieck (in press) found that a number of bird species which occurred in post-burn stands were not found in post-clearcut stands. Even though residual structure was retained in the clearcuts in this study, the density of snags was apparently not enough for certain species. Even more striking is the finding from Scandinavia (Esseen et al. 1992) and recently from Saskatchewan (Ty Cobb, University of Regina, personal communication) that certain beetle species require burned-wood habitats. This implies that even with structural retention in clearcuts there is also a need for actual burned habitat.

Concern over this threat is moderated by the fact that wildfires are still very extensive in northern Saskatchewan, in spite of fire suppression.

Changes in forest due to fire suppression

This threat represents an alteration of habitats rather than a complete loss. Suppression of forest fires, while a high social priority, can also be seen as interfering with the natural disturbance regime that created the forest landscape. In the United States, Wilcove et al. (1998) found that disruption of fire ecology is a threat to 14% of imperilled species.

In Saskatchewan, forest fire suppression has probably led to an unnaturally high proportion of mature and old stands, but the natural proportions were highly variable through time (Andison 1998, Armstrong 1999), so it is not clear that maintaining some exact set of proportions is as critical as maintaining good representation of all age classes. Under current conditions, the percentages of forest age classes result from interaction between the wildfire regime and the timber harvesting regime. Forest management plans developed by the major timber companies undertake to maintain representative amounts of the various age classes, which probably addresses most of the concern over age distributions.

However, as discussed under *Community changes in clearcuts compared to burns*, post-clearcut stands are not a complete substitute for post-burn stands of the same age, and fire suppression eliminates habitat for species requiring high snag density and burned-wood substrates. This concern is moderated by the fact that wildfires are still very extensive in northern Saskatchewan, and probably will continue to be so.

Loss of burn habitats due to fire salvage

While burned habitats are still very extensive in Saskatchewan, salvage logging removes the physical structure and burned-wood substrate needed by many species.

Fire salvage has increased dramatically in recent years, with large companies moving into the province for this purpose. However, it is concentrated in burns close to existing access roads. Wood can only be harvested for two to three years after the burn before quality declines excessively, and burned areas of small trees are not worth harvesting. Guidelines prevent harvesting in riparian areas and steep slopes. Because of these constraints, the amount of burned wood harvested is estimated at about 25% (Gord Frey, SERM, personal communication).

Concern over this threat is moderated by the limited percentage harvested. However, concern could increase in the future if harvest intensity were to increase, in the absence of policy aimed at conserving representation of burn habitats.

Changes in grasslands due to fire suppression

This threat represents an alteration of habitats rather than a complete loss. The grasslands of southern Saskatchewan naturally experienced frequent fires, which have been mostly eliminated since settlement. In a review of threats to mostly native areas in the Northern Great Plains of the U.S. and Canada, Nature Conservancy (1999) rated "loss of fire regime" as the second most serious threat. While these changes probably affect all of our grasslands, they are most apparent in the Aspen Parkland, where invasion by shrubs and aspen suckers is clearly related to fire suppression (e.g. Anderson and Bailey 1980), and is reducing the area of remnant fescue prairie. Fire suppression may also contribute to stabilization of sand dunes, reducing habitat for certain rare species associated with active dunes (Gummer and Barclay 1997).

Habitat loss due to clearing/breaking for agriculture

Clearing and breaking of land for agriculture causes an obvious, direct loss of native habitats. According to Mineau and McLaughlin (1994), conversion of prairie has a disproportionately large effect on biodiversity compared to other kinds of native vegetation because half of Canada's endangered and threatened birds and mammals are prairie species. Habitat loss by breaking of prairie is considered a major threat to a number of rare species, such as burrowing owl (SERM no date), long-billed curlew (De Smet no date), sage grouse (Aldridge 1999) and Powell's saltbush (Gerry 1998). Habitat loss is considered by far the biggest threat to insect diversity (Ken Pivnick, entomological consultant, personal communication). The Breeding Bird Survey has shown a general decline in abundance of grassland bird species which is probably related to agricultural conversion (Neave et al. unpublished). Godwin et al. (1998) showed the greatly reduced diversity in several taxonomic groups on cultivated land compared to even small remnants of native prairie.

Agricultural conversion also includes establishment of tame forage stands. Because these are perennial grasslands, the loss of habitat is not as extreme as in the case of annual cultivation. Bird communities have been found to be similar between crested wheat grass stands and native grassland, but smooth brome stands have much reduced bird diversity (Steve Davis, Saskatchewan Wetland Conservation Corporation, personal communication). Even annual crops have some habitat value. Neave et al. (unpublished) interpreted the reduction in summerfallow from 1981 to 1996 as beneficial for wildlife because a standing crop provides more habitat (e.g. nesting cover for waterfowl) than summerfallow. According to Mineau and McLaughlin (1994), conservation tillage practices maintain higher invertebrate diversity and reduce damage to bird nests, compared to traditional tillage practices. Establishment of shelterbelts may help to provide habitat for some groups such as birds (Mineau and McLaughlin 1994). However, Godwin et al. (1998) found that shelterbelts were much less significant for overall biodiversity than retained patches of native vegetation.

Another component of agricultural conversion is the clearing of forest in the Aspen Parkland and Boreal Transition ecoregions. It is estimated that only 22% of the forest remains in the fringe area (i.e. the Boreal Transition), with obvious impacts on habitat for forest species such as Neotropical migratory birds (Keith Hobson, Canadian Wildlife Service, personal communication).

While road development causes a major loss of habitat, undeveloped road allowances may provide some of the few areas of perennial cover in heavily cultivated landscapes. These artefacts of the land survey system should be retained for their habitat value, rather than added to the adjacent cultivated acreage. Even the ditches of developed roads may have habitat value in areas of extensive cultivation.

The extent of remaining habitat can be seen in the following data. The percentage of non-cultivated land (calculated by subtraction from the percentage of cultivated land given in SERM 1995, 1997) could include tame pasture and miscellaneous land uses. Estimates of the percentage of native vegetation from other sources are somewhat smaller because of exclusion of these other uses. These figures show that about three-quarters of the native vegetation in the prairie and parkland has been lost to agriculture, with highest losses in the heavily farmed Moist Mixed Grassland Ecoregion. Because the remaining native vegetation includes wetlands and other kinds of azonal vegetation, the loss is probably higher for upland vegetation. The Boreal Transition, in which most of the original vegetation was forest, is about half cultivated, while cultivation is negligible in the ecoregions further north.

	percent non-cultivated		**percent native vegetation**	
Prairie Ecozone	32	*	24	**
Cypress Upland	79	*		
Mixed Grassland	39	*	31	***
Moist Mixed Grassland	20	*	14	***
Aspen Parkland	31	*	24	***
Boreal Plains				
Boreal Transition	51	*		
Mid-Boreal Upland	99	*		
Mid-Boreal Lowland	99	*		

Sources:
* State of the Environment Reports (SERM 1995, 1997), based on census data for Saskatchewan.
** Neave et al. unpublished, based on census data for the three Prairie Provinces.
*** James et al. 1999, based on Landsat-derived mapping for portions of the Saskatchewan ecoregions

The rate of conversion through time can be estimated from census data. Coupland (1987) estimated a decline in the percentage of mixed prairie remaining in Saskatchewan from 42% in 1941 to 31% in 1981, for an average loss of 0.28 % of total area per year. Similar calculations by Neave et al. (unpublished) for the Prairie Ecozone in the three Prairie Provinces from 1981 to 1996 give a loss of 0.15 % per year. This suggests that the rate of decline is slowing down. In other words, most of the loss has already occurred.

Changes in range condition and habitat due to livestock grazing

This threat represents an alteration of habitats rather than a complete loss. Livestock grazing clearly causes changes in vegetation which are expressed as reduction in range condition. However, this does not necessarily imply a threat to biodiversity. Bai et al. (1999) found either no change or a slight increase in plant species diversity in grazed grasslands compared to ungrazed, while Groskorth and Gauthier (1999) found an increase in plant species richness with reduction in range condition. The situation is probably more complex than a simple increase in one direction. McCanny et al. (1999) examined diversity of plants, songbirds, and large insects at Grasslands National Park and found that some species occur in grazed habitats and others in ungrazed. Maximizing regional biodiversity requires that there be areas of both grazed and ungrazed grassland. Similarly, Bock et al. (1993) in a review of Great Plains grasslands in the United States found that 9 species of birds respond positively to grazing and 8 respond negatively. This suggests that the least desirable situation is uniformity of grazing management. In Saskatchewan the threat may be greatest in the Moist Mixed Grassland and Aspen Parkland Ecoregions, where grazing pressure is more uniformly heavy.

Heavy grazing does reduce habitat for species requiring taller vegetation structure (e.g. waterfowl nesting cover) (Mineau et al. 1994). Overgrazing is considered a threat to sage grouse (Aldridge 1999). Grazing in forest vegetation is thought to reduce habitat for birds which nest in heavy shrub or herbaceous layers (Al Smith, Canadian Wildlife Service, personal communication), and reduces browse availability for big game (Thorpe 1978).

Damage to riparian vegetation by livestock grazing

This threat represents an alteration of habitats rather than a complete loss. Riparian vegetation along streams and other water bodies often receives heavy grazing impact because of the lush forage and proximity to drinking water. In a survey of 600 sites in agricultural Saskatchewan, about 60% of the length of creeks had grazing along the shorelines, and of this 20% had heavy or extreme grazing (Tom Harrison, Saskatchewan Wetland Conservation Corporation, person communication). Because of the importance of riparian habitats to many species, this probably has a bigger effect on biodiversity than upland grazing. In a review of riparian habitats in the western United States, Bock et al. (1993) found that 8 species of birds respond positively to grazing while 17 respond negatively, with others showing mixed responses.

Flooding of riparian ecosystems due to dam construction

Damming to create a reservoir eliminates terrestrial habitats. This impact is particularly important because it is concentrated on riparian zones, which contribute disproportionately to biodiversity. For example, the creation of Lake Diefenbaker destroyed a significant percentage of the riparian cottonwood forest in Saskatchewan. For analysis of the extent of this damage in Saskatchewan, see *Change from stream to reservoir due to dam construction* in Section 2.3.1.

Changes in riparian habitats downstream from dams

Damming can have downstream effects on riparian ecosystems, by eliminating flooding events which are important to these ecosystems. For example, it is thought that riparian cottonwoods are failing to regenerate on some dammed prairie rivers because they require flood-deposited silt (Bradley and Smith 1986). The E.B. Campbell Dam has eliminated spring flooding of the Cumberland Delta, causing large ecosystem changes such as death of willows which may contribute to declining moose populations (Rhys Beaulieu, SERM, personal communication). Because these are long-term changes to the dynamics of the riparian ecosystem, the impact is considered relatively severe.

Habitat loss due to road construction

Saskatchewan's extensive road network is taken for granted by most people, yet has been identified as one of the serious threats to biodiversity.

The total lengths and areas occupied by roads in Saskatchewan ecoregions have been estimated using databases provided by Saskatchewan Highways and Transportation (Anna Czarnecki, Allan Schaan, personal communication). This required some approximations. One set of data was for provincial highways, and was organized by Sask. Highways regions. The percentages in the various ecoregions were roughly estimated by comparing maps. The other dataset was for municipal roads and was organized by rural municipality (r.m.); one category of these called "prairie trails" was omitted from the analysis. Again, the r.m.'s were assigned to ecoregions by comparison of maps. This calculation does not take into account forestry roads which are not part of the provincial highway system, for which we do not have any data.

This analysis, while approximate, shows that there is not only an enormous length of road in southern Saskatchewan, but that road rights-of-way also account for a significant area of land, as high as 2% of the most densely populated ecoregions. About one-quarter of this area consists of the unvegetated road surface, while the balance consists of ditches which usually have perennial vegetation cover. Relative to the maximum area of native vegetation, ditches represent habitat loss, but in heavily cultivated regions they may be the only significant areas of perennial vegetation so may have relative habitat value.

ecoregion	**length (km)**			**right-of-way area (km2)**				
	municipal	**highway**	**total**	**municipal**	**highway**	**total**	**ecoregion area**	**% in road**
CU	2,042	84	2,126	43	4	48	4,900	1.0
MG	49,847	5,076	54,923	1,064	263	1,327	87,000	1.5
MMG	49,392	4,077	53,469	1,064	213	1,277	68,000	1.9
AP	55,123	7,700	62,823	1,262	399	1,661	81,600	2.0
BT	27,422	3,924	31,346	651	163	814	54,000	1.5

MBU	1,838	3,076	4,914	43	124	168	101,000	0.2	+ forestry
MBL	143	368	511	3	15	18	21,500	0.1	roads
CRU	0	1,380	1,380	0	55	55	113,100	0.0	
ATP	0	460	460	0	18	18	74,000	0.0	
TLU	0	46	46	0	2	2	18,100	0.0	
SLU	0	0	0	0	0	0	29,000	0.0	

While it might be thought that road construction for agricultural purposes should have slowed down, in fact calculations based on the municipal roads database show and average increase of 1.98 % per four-year period throughout the span from 1961 to 1996. Moreover, many of the remaining areas of native vegetation, in which the prevailing use as rangeland does not require an extensive road network, are increasingly being impacted by proliferation of roads for oil and gas development.

Road development in the commercial forest is very extensive, and is considered to be the biggest single impact on biodiversity in this part of the province (Ed Kowal, SERM, personal communication). A study of three harvest areas in the Prince Albert Model Forest found that the loss of land attributable to roads ranged from 2.0 to 4.2% (Golder Associates 1994), although in areas which are not subject to active timber harvesting this figure would obviously be less. This suggests that forestry roads could add significantly to the above totals, for the ecoregions with commercial forestry.

Habitat loss due to other linear developments

Linear developments such as pipelines and powerlines also require alteration of natural ecosystems. No specific information was found on the degree to which this threatens biodiversity in Saskatchewan.

Habitat loss due to urban/industrial development

Development of urban areas and industrial sites obviously eliminates native habitats. This impact is greatest in the most populated parts of the province. Included under this threat are not just cities, but towns, villages, resort developments, etc. No data have been found on the actual area involved.

In addition to the habitat loss caused by these developments, they can contribute to mortality of migrating birds by creating obstacles. An unknown but possibly significant number of birds die by collisions with buildings, radio towers, etc.

Habitat loss due to coal mining

Strip mining for coal in southeastern Saskatchewan causes a massive disturbance to the surface soil and vegetation. Some mining has affected areas of native grassland, including some with rare species such as big bluestem. Even if the coal spoils are levelled after mining, the material is highly sodic, interfering with subsequent restoration. The area affected is relatively limited in this province, but the impact is severe where it happens.

Disturbance of ecosystems due to recreation traffic

Probably the greatest impact of outdoor recreation on biodiversity is the resulting development (roads, resorts, golf courses, downhill ski areas, cottage subdivisions) which occurs in largely native areas. However, this is really part of the larger topic of urban/industrial development, discussed earlier. Apart from development, there may be some local effects of recreational use, such as compaction of snow and vegetation caused by snowmobiles or all-terrain vehicles. One of the concerns raised for rare plants in the Athabasca sand dunes is the possibility of damage due to foot or ATV traffic by recreational users (Argus 1998).

Disturbance of ecosystems due to military activities

Impact on ecosystems due to military activities occurs in two areas. The Dundurn Military Camp, located in a block of sand dunes in the Moist Mixed Grassland Ecoregion, receives fairly heavy impact from construction of facilities, heavy vehicle traffic, shelling, and increased fire. This impact may contribute to spreading of exotic species in the area (Bert Weichel, environmental consultant, personal communication).

The Primrose Lake Air Weapons Range is a large block of land used by the military in the Mid-Boreal Upland Ecoregion. However, the impacts are limited to a few small areas used for live-bombing. Impacts in this area due to fire-salvage logging and oil and gas development are thought to be of greater concern than military activities (Randy Seguin, SERM, personal communication).

Effect on migratory species of habitat loss outside of Saskatchewan

Habitat loss outside of Saskatchewan presents a threat to our biodiversity because of the effects on migratory birds as well as other migratory animals (e.g. monarch butterflies). Neotropical migrants (i.e. birds that winter in the tropics of South and Central America) are known to be declining, but it is not known whether the cause lies in their wintering or breeding habitat.

One-third of Saskatchewan bird species winter in the tropics, so loss of habitat there could be critical. The ratio of winter to summer habitat could be skewed such that there is an excess of summer habitat while winter habitat is saturated, possibly resulting in males and females being too dispersed over the breeding habitat for efficient breeding. Effects are probably more severe in the forest regions than in the grassland, because there is a higher proportion of Neotropical migrants breeding in the forest (Al Smith, Canadian Wildlife Service, personal communication).

The assessed severity of this threat is increased by the known decrease in Neotropical migrants and the known loss of habitat in the tropics, but is moderated by the absence of research showing that this habitat loss is actually affecting populations of our species.

2.2.2 Habitat fragmentation

Fragmentation due to timber harvesting

Clearcuts cause fragmentation of mature forest habitats, which is beneficial to "edge" species of wildlife but harmful to species requiring forest interior habitats.. However, because of the regrowth of forest in clearcuts, this fragmentation is less severe than that which occurs with agricultural clearing (Von Sacken 1998). In a general review, Eng (1998) concluded that the evidence of loss of diversity due to fragmentation by logging is weak. One of the threats in fragmentation of forest habitats is increase in nest predation. However, in a Saskatchewan study, Hobson (1996) found that nest predation at logged edges was only a little higher than in the forest interior.

A possible indirect effect of forest fragmentation may occur through increase of white-tailed deer (an edge species), prompting an increase in wolf populations, leading to an increase in predation on the rare woodland caribou (Rhys Beaulieu, SERM, personal communication).

Fragmentation due to clearing/breaking for agriculture

Saskatchewan prairie is highly fragmented by agriculture, with most patches of prairie in the smaller size classes (James et al. 1999). Studies of Saskatchewan prairie patches ranging from 18,000 ha down to 7 ha found reductions in numbers of beetle and spider species with smaller patch area (Jeanette Pepper, Saskatchewan Conservation Data Centre, personal communication). In a study of grassland birds, Sprague's pipit was found only in grassland patches above a certain size (Steve Davis, Saskatchewan Wetland Conservation Corporation, personal communication).

Agricultural clearing in the Boreal Transition Ecoregion has also caused fragmentation of remaining forest habitats. Zuidema et al. (1996) reviewed studies from around the world showing reduced reduction in species diversity with reduction in size of forest fragments. Hannon (1993) found this relationship for birds in Alberta woodlots surrounded by agriculture. Hobson (1996) found elevated nest predation in forest remnants fragmented by agriculture, probably because of a greater diversity of predators.

Fragmentation due to road construction

Research from other areas has shown that some species of insects and small mammals are prevented from movement by road barriers, even in some cases narrow unpaved roads through forest or grassland (Noss and Cooperrider 1994). Roads may even fragment populations of larger animals, as suggested by work on the rare woodland caribou in Saskatchewan (SERM 1999).

Another aspect of fragmentation of terrestrial habitats by roads is the actual mortality of animals caused by vehicles. Aldridge (1999) considered this to be a threat to sage grouse which may travel and even form leks on roads. Holroyd (1999) considered traffic deaths a possible threat to burrowing owls.

Fragmentation due to other linear developments

Linear developments such as pipelines and powerlines may contribute to fragmentation of natural ecosystems. However, the fact that these areas are usually revegetated implies that their impact is less than that of roads.

2.2.3 Exotic invasion

Invasion of upland vegetation by exotic plants

In Canada, exotic plant species now make up 30% of the flora (Mosquin et al. 1995). Invasion of native grassland by exotic plant species is considered a major problem in Saskatchewan. Perhaps the most severe problem is that of invasion by smooth brome grass in the aspen parkland (Romo et al. 1990), but a number of other exotic perennials such as crested wheat grass, leafy spurge, Canada thistle, and quack grass have also invaded significant areas. Another extensively established species in the parkland and in moist areas throughout the prairies is Kentucky blue grass, but there is controversy over how much of this is of exotic origin (Thorpe and Godwin 1993). Invasive exotics can completely dominate grasslands and drastically reduce the diversity of native plants (Godwin et al. 1998).

Exotic invasion is not yet a serious threat in the forest regions, but there is some invasion of species such as Kentucky blue grass, quack grass, Canada thistle, and caragana in the southern edge of the forest, which is affected by proximity to settlement and livestock grazing.

Replacement of native by exotic plant communities affects their habitat value for other organisms, depending on the exotic species. Crested wheat grass stands have similar bird communities to native prairie, but smooth brome stands are much reduced in diversity (Steve Davis, SWCC, personal communication). Godwin et al. (1998) found five or six grassland bird species on a block of native prairie and only one on a nearby smooth brome field. Wilson and Belcher (1989) found that two out of eight grassland bird species were significantly more abundant on native than tame grassland.

Invasion of exotic birds

Exotic birds such as starling, house sparrow, and domestic pigeon cause a number of ecological problems (Mosquin et al. 1995, Pimentel et al. no date). In Saskatchewan the biggest concern is the use by starlings and house of sparrows of nest cavities needed by native species such as mountain bluebird. However, invasion by exotic birds is not yet considered a major problem here (Al Smith, Canadian Wildlife Service, personal communication).

Another related concern is with native species that have expanded their ranges because of human impact. An example is the brown-headed cowbird, which has expanded northward because of fragmentation of the forest, and which impacts on other birds by nest parasitism. However, range variations of native species, which must have occurred to some extent under natural conditions, are of lesser concern than the introduction of exotics. Under climate change we can expect to see more northward range changes; the native species of greatest concern will be the ones that are unable to expand their ranges.

Invasion of exotic insects

The best known exotic insect problem is that of the seven-spotted lady beetle, which was intentionally introduced and has become the dominant lady beetle in southern Saskatchewan, probably displacing native lady beetle species (Ken Pivnick, entomological consultant, personal communication). Cabbage butterflies may be displacing native butterflies that feed on plants in the mustard family (Ken Pivnick, personal communication). According to Mosquin et al. (1995), honey-bees compete with native pollinating insects for nectar and pollen. A recent study of native grasslands in Saskatchewan found that non-native beetle species made up 8% of beetle diversity (Anonymous 1999a). While the extent to which these exotic species are reducing diversity of native species is not known, this appears to be a potential consequence.

Invasion of exotic microbe pests

Invasion of exotic microbes is another possibility. Some well-known examples are Dutch elm disease and chestnut blight, which have killed millions of trees and substantially altered eastern forest ecosystems (Pimentel et al. no date). New wildlife diseases could arrive in Saskatchewan as a result of climate change; however, our understanding of these interactions is limited, and many disease problems go undetected (Gary Wobeser, Western College of Veterinary Medicine, personal communication).

Predation by domestic cats and dogs

Studies from the United States indicate that domestic cats, especially in rural areas, kill significant numbers of birds (estimate of 39 million per year in Wisconsin) (Coleman et al. no date, Pimentel et al. no date). Cat predation is considered to contribute to the endangerment of piping plover and loggerhead shrike (Coleman et al. no date), while De Smet (no date) listed cat predation as one source of nest mortality for long-billed curlew. On the basis of this information, many people consider cat predation to be an important threat in Saskatchewan. We have tentatively assigned it the “moderate” level of severity, based on the reasoning that predation rates may be lower here because of lower human population density in rural areas and remoteness from settlement of much wildlife habitat. However, data for Saskatchewan conditions are really needed to provide a better basis for this rating. Domestic dogs may also kill deer and other animals (Mosquin et al. 1995, Pimentel et al. no date), but are less likely than cats to pose a threat to biodiversity.

Dispersal of exotics due to clearing/breaking for agriculture

Agricultural fields provide open habitats for establishment of exotic plant species. They can then act as sources for invasion of adjacent native habitat. Godwin et al. (1998) found that the percentage of exotic species in grassland remnants in Saskatchewan clearly increases with proximity to the agricultural edge of the remnant.

Spread of disease from livestock operations and game farms

There are a number of diseases that could spread from domestic animals or game farms to wild populations. For example, *Parelaphostrongylus tenuis*, a parasite of deer, elk, and moose in eastern North America, could be brought into Saskatchewan by importation of game farm stock (Slattery and Portman 1999). However, some experts consider the risks to be minimal. For example, even when brucellosis and tuberculosis were common in cattle they apparently did not spread to wild animals (Al Choquer, Saskatchewan Agriculture and Food, personal communication). Fencing regulations for game farms are intended to minimize contact with wild animals (Wayne Gosselin, Saskatchewan Agriculture and Food, personal communication).

Another concern that has been raised concerning game farming is that it may occupy large areas of the "marginal" lands which are the main areas of wildlife habitat in southern Saskatchewan, reducing habitat for wild big game either by overgrazing or because of game-proof fencing (Slattery and Portman 1999). While the area occupied is probably not great enough at present to cause a major concern, this could increase with future expansion of the industry.

Dispersal of exotics due to road construction

Road construction appears to contribute significantly to the dispersal of exotic plants. A road network is also a network of open-soil habitats which allow exotics to establish and spread anywhere the roads go. Exotics such as smooth brome spread quickly along ditches, providing a source for slower invasion of adjacent native habitats. Belcher and Wilson (1989) found that almost all of the leafy spurge infestations they studied in southern Manitoba were centred on roads, trails, or fireguards.

Dispersal of exotics due to other linear developments

Soil disturbance due to linear developments such as pipelines and powerlines allows establishment of exotic plant species. The practice of reseeding corridors with native species helps to reduce this threat, but this is not legislatively required. Even use of native grass seed does not completely eliminate the threat, because there is no requirement that it be certified free of exotics such as downy brome grass.

2.2.4 Pollution

Vegetation damage due to acid precipitation

The acid precipitation situation in Saskatchewan is discussed in more detail under *2.3 Threats to Aquatic Biodiversity*. Acid deposition could have impacts on terrestrial vegetation, especially in close proximity to pollution sources (Hammer 1980). In eastern Canada, acid rain is considered the main threat to fungal biodiversity (Hawksworth 1992). However, there is no evidence that damage to terrestrial vegetation has occurred yet in Saskatchewan (Hammer 1980), so this is mostly a future threat depending on increase of industrial emissions.

Pollution due to oil/gas extraction

Oil and gas extraction can lead to pollution of soils and water bodies through spills, leakage from storage facilities, etc. Spills are usually small in spatial extent. They are usually cleaned up quickly, but cleanup involving soil removal could be a fairly heavy impact in an area of native vegetation.

Vegetation damage due to potash mines

Salt emissions from potash mines have been shown to damage aspen stands in the vicinity of the mine (Townley-Smith 1977). However, the area affected is small and emissions controls have probably reduced the amount of damage which occurs.

Vegetation damage due to other industry

Industries such as smelters, pulp mills, and factories may emit air pollution which damages surrounding vegetation. However, the amount of such industry is limited in Saskatchewan compared to other provinces. No information was found on the degree to which this threatens biodiversity.

Air pollution due to greenhouse gases

Another source of air pollution is emission of greenhouse gases, in part due to industry, but also in part due to the activities of everyone using vehicles, heating houses, and so on. The indirect effects on climate change have already been discussed. No information has been found on the degree to which greenhouse gas emissions directly threaten biodiversity.

Poisoning of non-target wildlife due to pesticide use

Areas in the Canadian prairies treated with insecticides and herbicides are increasing (Mineau and McLaughlin 1994). Some insecticides are known to have had major effects on birds, but regulation has improved in recent years and the most damaging chemicals such as the organochlorines (e.g. DDT, dieldren) have been eliminated from use in Saskatchewan, although they are still used in some developing countries (Mineau and McLaughlin 1994). Birds such as raptors that were threatened by organochlorines have apparently recovered since the banning of these chemicals (Martin et al. 1996, Houston 1999). More recently, the granular formulation of carbofuran has been deregistered because of evidence of damage to birds (Health Canada 1995).

However, even if harmful effects on the more visible species such as birds are being closely regulated, there could be unknown effects on non-target invertebrates, soil microbes, etc. from the current heavy use of chemicals. Reduction of invertebrate populations by insecticides could indirectly affect birds by reducing their food supply (Martin et al. 1996). There could also be sublethal effects which do not attract the attention of regulators. Pesticides are known to cause genetic changes such as evolution of resistance in target species, while there could also be genetic effects on non-target species (Mineau and McLaughlin 1994). This raises the need for ecosystem-level studies of the impacts of pesticides, as opposed to toxicity-testing for a few species.

70% of the amount of pesticides used in Canada consists of herbicides, and less is known about non-target effects of these chemicals than for insecticides (Mineau and McLaughlin 1994). There could be effects on adjacent native vegetation and wetland plants, with indirect effects on animals that use them (Forsyth 1989, Martin et al. 1996). Herbicides may also impact directly on invertebrates and microbes (Mineau and McLaughlin 1994).

In the forest, the main use of insecticides is for control of spruce budworm, but Saskatchewan programs have used Bt, a biological control agent with less potential for nontarget damage than the chemical insecticides that have been used for budworm control in eastern Canada. However, Bt could still be having unknown effects on nontarget butterflies and moths.

Another aspect of pesticides is the use of chemicals to kill large predators such as coyotes. This raises the concern of poisoning of non-target species, including rare ones such as the reintroduced swift fox.

According to Mineau and McLaughlin (1994), there is no evidence that any pesticides in current use have had a long-lasting effect on biodiversity. While regulation of pesticides has undoubtedly improved, the widespread and increasing use of pesticides and the complexity of potential ecological effects indicate that concern is still warranted.

Loss of migratory birds due to pesticide use outside of Saskatchewan

Pesticides which have been banned in the United States and Canada because of their harmful effects on birds and other animals are still used in other countries (Brian Johns, Canadian Wildlife Service, personal communication). This creates a serious threat to Saskatchewan biodiversity because of the effect on migratory birds (especially raptors and shorebirds) that winter in South and Central America.

2.2.5 Overharvesting

Overharvesting of big game

Most big game hunting is regulated according to game management principles. Nevertheless, there have been situations in Saskatchewan in which local populations of moose, elk, and mule deer have been overharvested (Al Arsenault, SERM, personal communication). However, these are still common species, and local population reduction is only a moderate threat to biodiversity. Even if small isolated populations (e.g. of elk in the prairies) are eliminated, these are recent migrants so are not thought to represent unique gene pools (Adam Schmidt, SERM, personal communication). The greatest biodiversity concern is with unregulated hunting of woodland caribou, which probably contributes to the threatened status of this species in Saskatchewan (Rock 1992).

Overharvesting of medicinal and other plants

Gathering of wild plants for medicinal and other purposes could reduce their populations, especially in the case of rare species. Declines of seneca-root and echinacea have been attributed to gathering (Bizecki Robson 1999). However there appear to be limited data on this issue.

2.2.6 Loss of genetic diversity

Loss of diversity in planted tree seedlings

The planting of tree seedlings in commercial forestry raises the possibility of extensive areas of forest with reduced genetic diversity. Rajora and Dancik (1996) found that planted white spruce in Saskatchewan had lower genetic diversity than old-growth forest and natural regeneration. This threat is moderated by the fact that it affects only a few species, and only those areas which are not naturally regenerated.

Loss of diversity in crop plants

Inclusion of agricultural crop plants in this discussion is debatable, because they are exotic species and not part of native biodiversity. However, the genetic diversity of crop plants is considered an important part of the globe's natural heritage, and is definitely at risk. The low diversity of crop plants used in Canada is discussed by Mineau and McLaughlin (1994). Much of the genetic diversity of plants such as wheat, barley, oats, rye, and pulse crops has been lost already. The original species such as wild emer wheat are threatened by habitat loss (due to agriculture and urban development) in countries where they are native, such as Turkey, Syria, Iraq, and Israel (S. Jana, University of Saskatchewan, personal communication).

One way in which this threat is being addressed is by seed banks which maintain live collections of a large number of varieties. The main seed bank for field crops in Canada is located at Agriculture Canada in Saskatoon, which has more than 110,000 samples of crop varieties as well as wild and weedy relatives of crop species. This seed bank is also beginning to collect native species (including rare species) from the grassland region of the Prairie Provinces, as a contribution to conservation of biodiversity (Richards and Kessler 1999).

Threats of genetically engineered crops

Genetic engineering is a rapidly developing technology for producing new crop varieties with properties not attainable by conventional breeding. Edge (1994) reviewed a number of concerns that have been raised, such as the development of increasingly invasive crop species, or the transfer of genes (e.g. for herbicide resistance) to wild relatives. However, he stated that there is a broad opinion in the scientific community that these risks are not significant.

2.3 Threats to Aquatic Biodiversity

2.3.1 Habitat loss and alteration

Shifts in ecoregions due to climate change

The threats due to climatic change discussed in the terrestrial section apply equally to aquatic biodiversity. For example, the decline of lake trout in southern boreal lakes could in part be due to climatic warming (Kevin Murphy, SERM, personal communication). Changes in aquatic ecosystems may not be only due to ambient temperature effects on organisms; there could also be changes in nutrient cycling which would eliminate habitat for some species (Guy Melville, SRC, personal communication).

Drainage of wetlands

Wetlands are major contributors to the biodiversity of the Prairies, but are often seen by farmers as wasted land and obstacles to field operations. For this reason, extensive areas of wetland habitat have been eliminated by drainage projects. The loss has been variously estimated at 40% for Saskatchewan (Anonymous 1999b) and 71% for the Prairie Provinces (Mosquin et al. 1995). Wetland drainage is most organized in the eastern part of agricultural zone, with planning at more than just the single farm level (Kevin Murphy, SERM, personal communication). Loss of habitat is thought to be most critical in the Assiniboine and Souris basins (Barb Hanbidge, Ducks Unlimited, personal communication). In the upper Assiniboine Basin, it is estimated that more than 50% of wetlands have been drained (Adam Schmidt, SERM, personal communication).

Some projects involve drainage of several small wetlands into one large one. While this may not appear to be a net loss, it means a change from ephemeral to permanent wetlands. This could result in loss of invertebrate species, some of which such as chironomid insects have many species which are unique to small areas (Kevin Murphy, SERM, personal communication).

Downstream effects of drainage of wetlands

The runoff from wetland drainage in agricultural areas may contain salts, pesticides, or fertilizers that affect diversity downstream (Mineau and McLaughlin 1994). In addition, wetland drainage may change the timing of downstream flows, possibly affecting species that use high flows as a cue for spawning (Kevin Murphy, SERM, personal communication). However, no information has been found on the degree to which this affects biodiversity in Saskatchewan.

Change in aquatic habitats due to channelization

Channelization is done to speed the flow through a stream system and reduce flooding, but this has impacts on fish habitat. In Saskatchewan, channelization has been most extensive on the Assiniboine and Qu'Appelle systems, although streams through urban areas are also highly channelized (Kevin Murphy, SERM, personal communication). It is thought that channelization of the Qu'Appelle River (along with damming) has contributed to the decline of bigmouth buffalo, by reducing the area of flooded vegetation needed for spawning (Goodchild no date). Water transfers occur earlier and faster than they would have naturally, so that the main flow is completed before the water is warm enough for bigmouth buffalo spawning (Ron Hlasny, SERM, personal communication).

Change from stream to reservoir due to dam construction

Dams have been widely built for flood control, water storage, and power generation, but they drastically alter aquatic habitats. Richter et al. (1997) found that damming is one of the top three threats to imperilled freshwater fauna in the United States, while Wilcove et al. (1998) found that 17% of imperilled species in the United States are threatened by dams and other barriers.

Dams cause a massive alteration of the aquatic ecosystem, with negative impacts on species that require flowing water, such as sturgeon. Reservoirs are actually structurally different from natural lakes because the outflow in a reservoir is from the water near the bottom (Guy Melville, SRC, personal communication).

While the large dams such as Gardiner, Nipawin, and E.B. Campbell on the Saskatchewan and Rafferty on the Souris are most visible, there are also a large number of small dams. PFRA has constructed approximately 12,000 dams in the Prairie Provinces, of which about half are in Saskatchewan, but few new ones are being built because of lack of suitable sites and because of environmental concerns (Harvey Filson, PFRA, personal communication).

Calculations based on a database provided by SaskWater (Don Anderson, personal communication) give a total number of about 8,400 water developments with a total area of 173,000 ha (including one hydroelectric development which was not included in the actual database). The vast majority are small (average area 1 ha) stock-watering reservoirs which account for only 6% of the total area. About 42% of the total area consists of a relatively small number of larger multiple-purpose developments (average area 1181 ha), while another 47% of the area consists mainly of Ducks Unlimited projects. The magnitude of this last component highlights the lack of an ecosystem perspective in past approaches to wildlife management.

For most of the major drainage basins in southern Saskatchewan, the area in water developments averages about 0.3% of the basin area, but the figure is 1.3% in the South Saskatchewan basin because of Lake Diefenbaker. Percentages based on the amount of stream and riparian area rather than total basin area would of course be much higher, representing a significant loss of habitat.

Changes in aquatic habitats downstream from dams

Dams impact on the quantity and quality of water downstream. In the case of Last Mountain Lake, many of the inflowing creeks have been dammed to create marshes for ducks, greatly reducing the input of freshwater. This is thought to have contributed to the increasing salinity of the lake, which is eliminating fish species such as the johny darter (Ron Hlasny, SERM, personal communication). The series of dams along the Qu'Appelle has reduced flooding of vegetation needed for spawning by bigmouth buffalo (Goodchild no date). In the case of the Rafferty Dam, the water quality in the Souris, which is normally low, is reduced even further because accumulation of organic matter in the reservoir leads to low oxygen levels in the bottom water, from which the outflow is drawn (Kevin Murphy, SERM, personal communication).

Downstream effects of irrigation

Limited information has been found on the extent to which this is a threat in Saskatchewan. In Alberta and the western United States, extreme drawdowns for irrigation have led to fish kills and occasional elimination of fish. This would have effects on other aquatic organisms since flow levels, oxygen levels, and water temperatures are all affected. Another potential problem with irrigation is the movement of fish into irrigation canals which may be blocked off (Ron Hlasny, SERM, personal communication).

Change in lake levels and river flows due to water diversion

Water diversion (i.e. diversion of flow from one stream to another) has been fairly limited in Saskatchewan, although there are some instances such as transfer from the South Saskatchewan to the Qu'Appelle caused by creation of the Lake Diefenbaker reservoir. This has changed the ecology of the Qu'Appelle system, for example by reducing the level of total dissolved solids in Buffalo Pound Lake (Ron Hlasny, SERM, personal communication). The possibility of large water diversions similar to the Churchill River diversion in northern Manitoba would present a huge threat to the diversity of northern rivers (Guy Melville, SRC, personal communication). Even smaller water diversions can cause changes in streamflow pulses which affect animals which use flow as a cue for spawning. Water diversion has also been used in Saskatchewan to stabilize levels in lakes and marshes, for recreation or duck habitat. This had led to conversion of water bodies which naturally went through wetting and drying cycles to more stable deep-water bodies, with loss of diversity associated with the fluctuating system (Kevin Murphy, SERM, personal communication).

Disturbance of ecosystems due to recreation traffic

Recreational use of lakes and rivers by motor-boats, personal watercraft, and so on could have physical effects on shorelines or bottom features which affect the aquatic ecosystem. No information was found on the degree to which this threatens biodiversity.

2.3.2 Habitat fragmentation

Barriers to dispersal due to dam construction

Dams are barriers to dispersal of fish and other aquatic organisms, which could limit the ability of populations to recolonize after local extirpation, or to migrate in response to climatic change (Kevin Murphy, SERM, personal communication). The series of dams along the Qu'Appelle are thought to have contributed to the decline of the bigmouth buffalo (Goodchild no date). Even on smaller streams, barriers could have a major impact on non-flying invertebrates which evolved in a prairie system where stream barriers did not occur (Kevin Murphy, SERM, personal communication).

Barriers to dispersal due to road construction

One effect of roads is create a barrier across streams. Even if culverts are installed to allow water flow, inadequate culvert design or installation can prevent movement of organisms in some circumstances. This can interfere with dispersal of aquatic species, similarly to dams (Kevin Murphy, SERM, personal communication).

2.3.3 Exotic invasion

Invasion of wetlands by exotic plants

The exotic plant which poses the greatest threat to wetlands is purple loosestrife, an escaped ornamental plant which crowds out native plants. It is widespread in Manitoba and eastward. There are currently about 40 small invasion sites in Saskatchewan, including sites in Regina, Moose Jaw, Saskatoon, and Yorkton (Angela Salzl, Canadian Wildlife Service, personal communication). Because of the difficulty of controlling purple loosestrife, it has the potential to spread to greater areas.

Other exotic plants which may pose threats to wetlands include scentless chamomile in the southeast and wild rice plantations in the north.

Invasion of exotic microbe pests

The possibility of invasion of exotic microbes, already discussed in the terrestrial portion, could apply equally to aquatic ecosystems.

Invasion of exotic fish and molluscs

Globally, invasion of exotic fish is a major threat to aquatic biodiversity (Waples 1995, Hindar and Jonsson 1995, Marsden 1995, Stiassny 1996). In the United States, exotic invasion is considered a threat to 53% of fish species listed as imperilled (Wilcove et al. 1998), while Richter et al. (1997) rated is as one of the top three threats to imperilled freshwater fauna.

In Saskatchewan, the only documented case is the reduction of the native bigmouth buffalo, attributed in part to the spread of the exotic common carp up the Qu'Appelle system (Goodchild no date). Carp are present in other stream systems, such as the Frenchman and the Whitesand, and probably represent the biggest exotic problem. The channel catfish, originally exotic to Saskatchewan, has also moved up the Qu'Appelle system. Saskatchewan has been spared problems with exotic minnows because of regulations prohibiting use of live bait. The movement of walleye around the province in stocking programs could lead to displacement of local genotypes, but studies have found little genetic difference among local populations. Many water bodies have been intentionally stocked with exotic trout species, but these populations have not spread and are not thought to pose a threat to biodiversity (Kevin Murphy, SERM, personal communication).

Other exotic species could become problems in the future. One example is the zebra mussel, which has caused major ecological and economic disruption in the Great Lakes (Marsden 1995). If zebra mussel arrived in Saskatchewan, for example attached to a boat, it could become a serious problem (Guy Melville, SRC, personal communication).

Dispersal of exotics due to water diversion

One of the major concerns globally about water diversion is the transfer of species between naturally separate river basins. However, few examples have been found in Saskatchewan. The Lake Diefenbaker reservoir led to diversion of water from the South Saskatchewan River down the Qu'Appelle River. This is thought to have allowed several fish species (sauger, long-nosed dace, black-nosed dace, and spoonhead sculpin) to disperse into the Qu'Appelle (Ron Hlasny, SERM, personal communication).

2.3.4 Pollution

Aquatic effects of acid precipitation

Acid precipitation is a major threat to aquatic biodiversity in eastern Canada, with poorly buffered lakes showing progressive elimination of fish and aquatic invertebrate species (Mineau et al. 1994). However, the amount of acid deposition is much less in the prairies. The main area of concern is the Precambrian Shield, where lakes have lower buffering capacity than further south, and where there are major sources of acid emissions at Fort McMurray and Flin Flon (Hammer 1980). However, there is not yet any evidence from Saskatchewan of aquatic damage such as fish kills attributable to acid precipitation, so it is probably not a major threat currently (Guy Melville, SRC, personal communication). This threat could increase to serious proportions in the future if there were major increases in industrial emissions impacting the susceptible Shield region.

Siltation/eutrophication due to clearing/breaking for agriculture

Agriculture exposes soil to accelerated water erosion, carrying soil material and nutrients into water bodies. Even though these are not “contaminants”, accelerated inputs can lead to major ecosystem changes. Eutrophication (i.e. increased nutrient status) leads to an increase in algal growth, which when it decomposes leads to reduction in oxygen concentration and elimination of species requiring high oxygen levels (Guy Melville, SRC, personal communication). Agriculture is probably the biggest source of siltation and eutrophication in Saskatchewan (Guy Melville, SRC, personal communication). For example, a major contributor to eutrophication of the Qu’Appelle system is input of phosphorus from agricultural runoff (Kevin Murphy, SERM, personal communication).

This concern is moderated by the fact that the grassland where most of our agriculture occurs is a region of naturally high sediment loads and nutrient levels in water bodies. However, even high-nutrient ecosystems can be altered by further increases in input (Guy Melville, SRC, personal communication).

Poisoning of non-target wildlife due to pesticide use

According to Goldsborough (1999), there is abundant evidence that prairie wetlands are being contaminated by agricultural pesticides. The discussion of potential pesticide effects to terrestrial ecosystems (in Section 2.2.4) applies equally to wetlands.

Siltation/eutrophication due to livestock grazing

Livestock grazing of riparian zones can cause accelerated siltation of water bodies. Houston (1996) considered this a potential threat to the western silvery minnow, a rare fish of the grassland region which is sensitive to siltation. However, there is little information about the extent of this in Saskatchewan.

Siltation due to roads

Roads and ditches expose the soil to water erosion, which, especially at stream crossings, can cause siltation of aquatic ecosystems. No specific information was found on the degree to which this threatens biodiversity in Saskatchewan. This may be a bigger problem in northern Saskatchewan where water bodies are not naturally exposed to high rates of siltation (Kevin Murphy, SERM, personal communication).

Pollution due to oil/gas extraction

Oil and gas extraction can lead to pollution of soils and water bodies through spills, leakage from storage facilities, etc. However, spills are usually small in spatial extent.

Water pollution due to metals mining

Metals mining in Saskatchewan is restricted to the Precambrian Shield and consists largely of uranium mines. Drainage from tailings into water bodies can cause pollution due to acidity, radioactivity and accumulation of heavy metals (including uranium). Part of the concern relates to the long life of these pollutants. This is a very localized problem, but can have significant impacts where it occurs (Guy Melville, SRC, personal communication). This may be affecting diversity of benthic organisms in the streams receiving effluent (Karsten Liber, University of Saskatchewan, personal communication). There is more concern about orphan sites than the better-regulated current mines (George Patterson, Saskatchewan Energy and Mines, personal communication). While mine effluent is localized, the number of mines in the uranium region may be having cumulative effects. However, a cumulative effects monitoring program conducted by SERM in this region has found little change in valued ecosystem components related to mining (Mark Getzlaf, SERM, personal communication).

Water pollution due to other industry

Other industrial sources of water pollution are limited in Saskatchewan, and little information has been found on threats posed by them to biodiversity. One possible source is pulp mill pollution, which can contribute nutrient inputs, biological oxygen demand, and toxic chemicals such as dioxins and furans (Guy Melville, SRC, personal communication). Another possible source is feedlots and pig barns. Spread of manure on land by feeding operations can lead to eutrophication and microbial loading of water bodies, particularly in the case of winter spreading where the spring melt creates a flush of runoff (Wayne Gosselin, Saskatchewan Agriculture and Food, personal communication).

Pollution due to sewage release

Sewage release into rivers contributes to eutrophication, and may also add specific pollutants such as metals. Sewage release affects a wide range of water bodies (including, for example, lakes affected by parks and cottage subdivisions), but the Qu'Appelle, Souris, and Assiniboine Rivers are thought to be particularly impacted (Kevin Murphy, SERM, personal communication). While it is clear that sewage release adds pollution to water bodies in Saskatchewan, little information has been found on implications for biodiversity.

Water pollution due to landfills

Drainage from landfills into water bodies is another potential source of pollution by nutrients and specific contaminants. However, no information has been found on threats to biodiversity.

2.3.5 Overharvesting

Overharvesting of fish species

In spite of regulated management of fish harvests, overharvesting has occurred in several instances. Lake trout have been greatly reduced in lakes such as Lac La Ronge (Guy Melville, SRC, personal communication), and probably extirpated from lakes such as Amisk, Pelican, and Mirond (Tom Maher, SERM, personal communication). Climate change may also contribute to the decline of southern lake trout populations (Kevin Murphy, SERM, personal communication). Lake sturgeon in the Saskatchewan system are also thought to have declined in part because of overharvesting (Guy Melville, SRC, personal communication). Walleye have been depleted in lakes such as Doré when road access allowed recreational fishing in addition to the commercial harvest (Kevin Murphy, SERM, personal communication). Fish populations in different water bodies develop genetic differences, so local extirpation can lead to significant loss of genetic diversity (Ryder and Scott 1994).

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APPENDIX A

SaskWater Classification of Drainage Basins and Sub-Basins

1 SOURIS RIVER BASIN

24 Souris River
50 Lower Souris River Group
51 Lower Souris-Pipestone Creek
68 Long Creek
69 Moose Mountain Creek
70 Yellow Grass Ditch Section
71 Tataswa Lake

2 MISSOURI RIVER BASIN

01 Lodge Creek
02 Battle Creek
03 Frenchman River
12 McRae Creek
13 Woodpile Creek
14 Lyons Creek
15 Coteau Creek
16 Whitewater Creek
17 McEachern Creek
18 Horse Creek
19 Rock Creek
20 East Poplar River
21 Poplar River
22 West Poplar River
39 Wildhorse Lake
40 Climax Group
41 Taits Lake
42 Bluff Creek
43 Coal Creek
44 Paisley Brook
45 Big Muddy Lake
46 Missouri Group
49 Green Lake

3 CYPRESS HILLS (NORTH SLOPE) BASIN

04 Many Island Lake
05 Bigstick Lake
06 Hay Lake
07 Crane Lake
08 Skull Creek
09 Antelope Lake
36 Great Sandhills Group

4 OLD WIVES LAKE BASIN

11 Old Wives (Johnstone) Lake
37 Willowbunch Group
38 Rush Lake
48 Shoe Lake Group

5 QU=APPELLE RIVER BASIN

23 Qu=Appelle River
27 Quill Lakes
47 Little Manitou Lake
72 Wascana
73 Moose Jaw Ridge

6 SOUTH SASKATCHEWAN RIVER BASIN

10 Swift Current Creek
30 South Saskatchewan River
54 Coteau Group
55 Luck Lake

7 NORTH SASKATCHEWAN RIVER BASIN

25 Manito Lake
29 North Saskatchewan River
53 Whitebear Lake
56 Goose Lake Group
58 Kindersley Group
59 Whiteshore Lake
60 Redberry Lake

8 SASKATCHEWAN RIVER BASIN

26 Lenore Lake Group
28 Carrot River
67 Saskatchewan River

9 CHURCHILL RIVER BASIN

34 Churchill River
61 Beaver River
63 Reindeer River
64 Wollaston Lake

10 LAKE ATHABASCA BASIN

35 Athabasca River
62 Clearwater River

11 ASSINIBOINE RIVER BASIN

31 Assiniboine River

12 LAKE WINNIPEGOSIS BASIN

32 Swan Lake

33 Red Deer River

57 Overflowing River

13 TAZIN RIVER BASIN

65 Tazin River

14 KASBA LAKE BASIN

66 Kasba Lake