Trends in breeding waterfowl in Canada

M. Fast, B. Collins and M. Gendron[1]

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[1] All authors are with the Canadian Wildlife Service, Environment Canada

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PREFACE

The Canadian Councils of Resource Ministers developed a Biodiversity Outcomes Framework[1] in 2006 to focus conservation and restoration actions under the *Canadian Biodiversity Strategy*.[2] *Canadian Biodiversity: Ecosystem Status and Trends 2010*[3] was a first report under this framework. It assesses progress towards the framework's goal of "Healthy and Diverse Ecosystems" and the two desired conservation outcomes: i) productive, resilient, diverse ecosystems with the capacity to recover and adapt; and ii) damaged ecosystems restored.

The 22 recurring key findings that are presented in *Canadian Biodiversity: Ecosystem Status and Trends 2010* emerged from synthesis and analysis of technical reports prepared as part of this project. Over 500 experts participated in the writing and review of these foundation documents. This report, *Trends in breeding waterfowl in Canada*, is one of several reports prepared on the status and trends of national cross-cutting themes. It has been prepared by experts in the field of study and reflects the views of its authors.

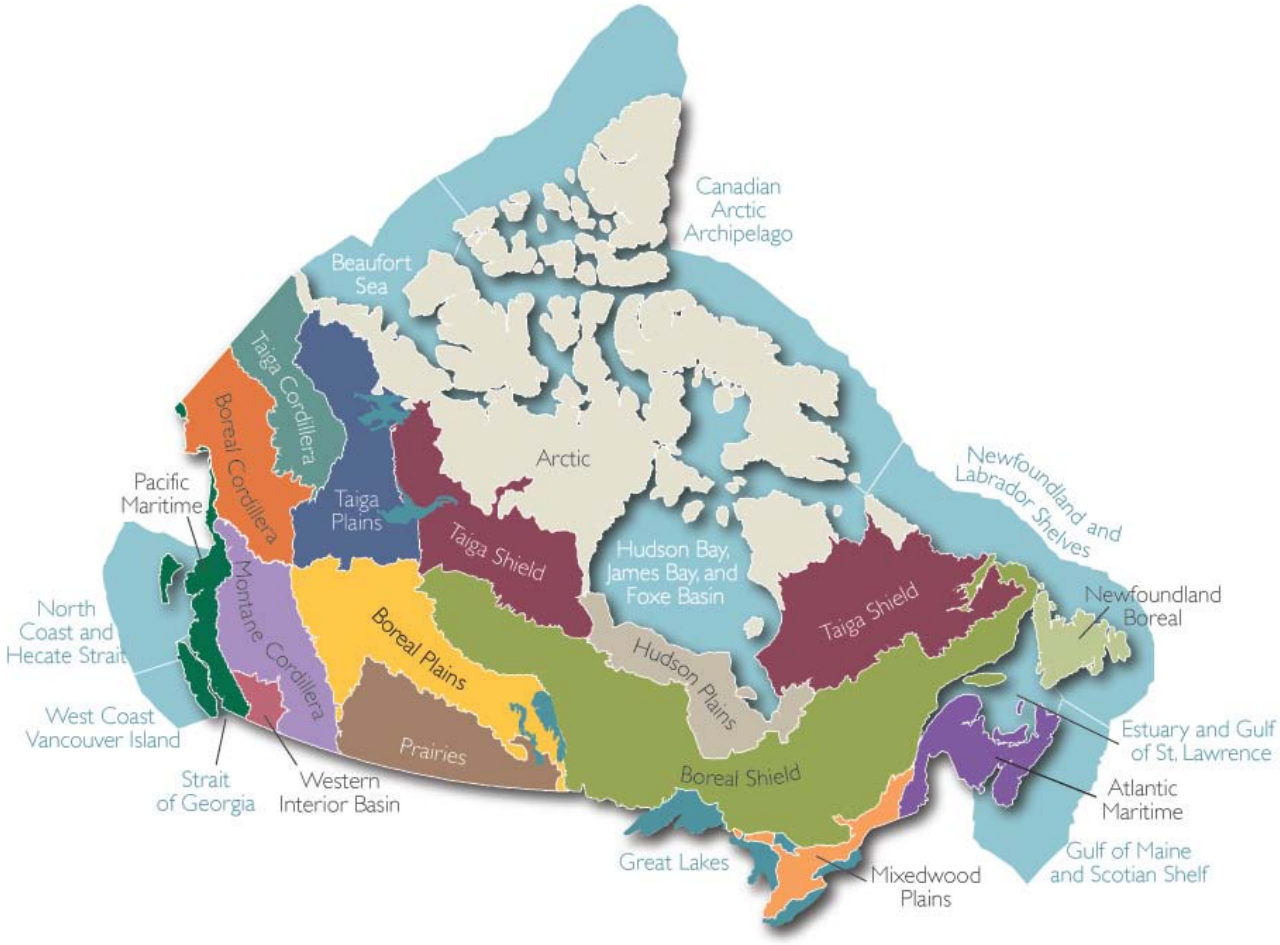
[1] Environment Canada. 2006. Biodiversity outcomes framework for Canada. Canadian Councils of Resource Ministers. Ottawa, ON. 8 p. http://www.biodivcanada.ca/default.asp?lang=En&n=F14D37B9-1

[2] Federal-Provincial-Territorial Biodiversity Working Group. 1995. Canadian biodiversity strategy: Canada's response to the Convention on Biological Diversity. Environment Canada, Biodiversity Convention Office. Ottawa, ON. 77 p. http://www.biodivcanada.ca/default.asp?lang=En&n=560ED58E-1

[3] Federal, Provincial and Territorial Governments of Canada. 2010. Canadian biodiversity: ecosystem status and trends 2010. Canadian Councils of Resource Ministers. Ottawa, ON. vi + 142 p. http://www.biodivcanada.ca/default.asp?lang=En&n=83A35E06-1

Ecological Classification System – Ecozones+

A slightly modified version of the Terrestrial Ecozones of Canada, described in the *National Ecological Framework for Canada*,[4] provided the ecosystem-based units for all reports related to this project. Modifications from the original framework include: adjustments to terrestrial boundaries to reflect improvements from ground-truthing exercises; the combination of three Arctic ecozones into one; the use of two ecoprovinces – Western Interior Basin and Newfoundland Boreal; the addition of nine marine ecosystem-based units; and, the addition of the Great Lakes as a unit. This modified classification system is referred to as "ecozones+" throughout these reports to avoid confusion with the more familiar "ecozones" of the original framework.[5]



[4] Ecological Stratification Working Group. 1995. A national ecological framework for Canada. Agriculture and Agri-Food Canada, Research Branch, Centre for Land and Biological Resources Research and Environment Canada, State of the Environment Directorate, Ecozone Analysis Branch. Ottawa/Hull, ON. 117 p. Report and national map at 1:7 500 000 scale.

[5] Rankin, R., Austin, M. and Rice, J. 2011. Ecological classification system for the ecosystem status and trends report. Canadian Biodiversity: Ecosystem Status and Trends 2010, Technical Thematic Report No. 1. Canadian Councils of Resource Ministers. Ottawa, ON. http://biodivcanada.ca/default.asp?lang=En&n=6F7EB059-1&wsdoc=A9376858-14D6-4C00-AB4F-2F3F8B97C84A

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INTRODUCTION

This report summarizes the results of an integrated analysis of trends of some breeding waterfowl populations in Canada. Although it would be ideal to document population estimates over a long period, such as the 1970s to present, most waterfowl data sets do not cover this full time period. In addition, not all ecozones+ are sufficiently captured by existing waterfowl monitoring programs. As such, only ecozones+ with adequate data coverage are included in this report. It is also important to note that not all breeding waterfowl species are captured by the existing monitoring surveys. For example, population trajectories of species occurring in low densities are often difficult to detect. This is an unfortunate reality because it is often these species (for example, seaducks) that are of greatest concern in terms of conservation. Finally, although Canada has several important waterfowl wintering and staging areas, data sets that could adequately capture long-term trends either do not exist or the analysis of these trends were not available at the time of writing. Below is a description of the methodologies used for the integrated analysis, followed by a description of trends of breeding waterfowl by ecozone+.

METHODOLOGY

Data Sources

Western ecozones+

CWS/USFWS Waterfowl Breeding Population and Habitat Survey

The best source of data for waterfowl population estimates for the purpose of this report come from the joint Canadian Wildlife Service (CWS) and U.S. Fish and Wildlife Service (USFWS) Waterfowl Breeding Population and Habitat Survey (U.S. Fish and Wildlife Service, 2007). This survey was initiated experimentally in 1947 and became operational in 1955 with cooperative surveys carried out every year since 1955. The primary purpose of the survey is to provide information on spring population size and trajectory for certain North American duck species. These data are used extensively in the annual establishment of hunting regulations in the United States and Canada and in providing long-term time series data critical to effective conservation planning. For more information on the survey see Smith (1995).

The traditional survey area only covers part of the country (Figure 1). Ecozones+ covered by it (Prairies, Boreal Plains, and Taiga Plains) are referred to as "western ecozones+" and data from this survey was used exclusively in the analysis for these ecozones+ in this report. We identified strata from the survey that were entirely contained within an ecozone+ and discarded any strata which straddled two or more ecozones+.

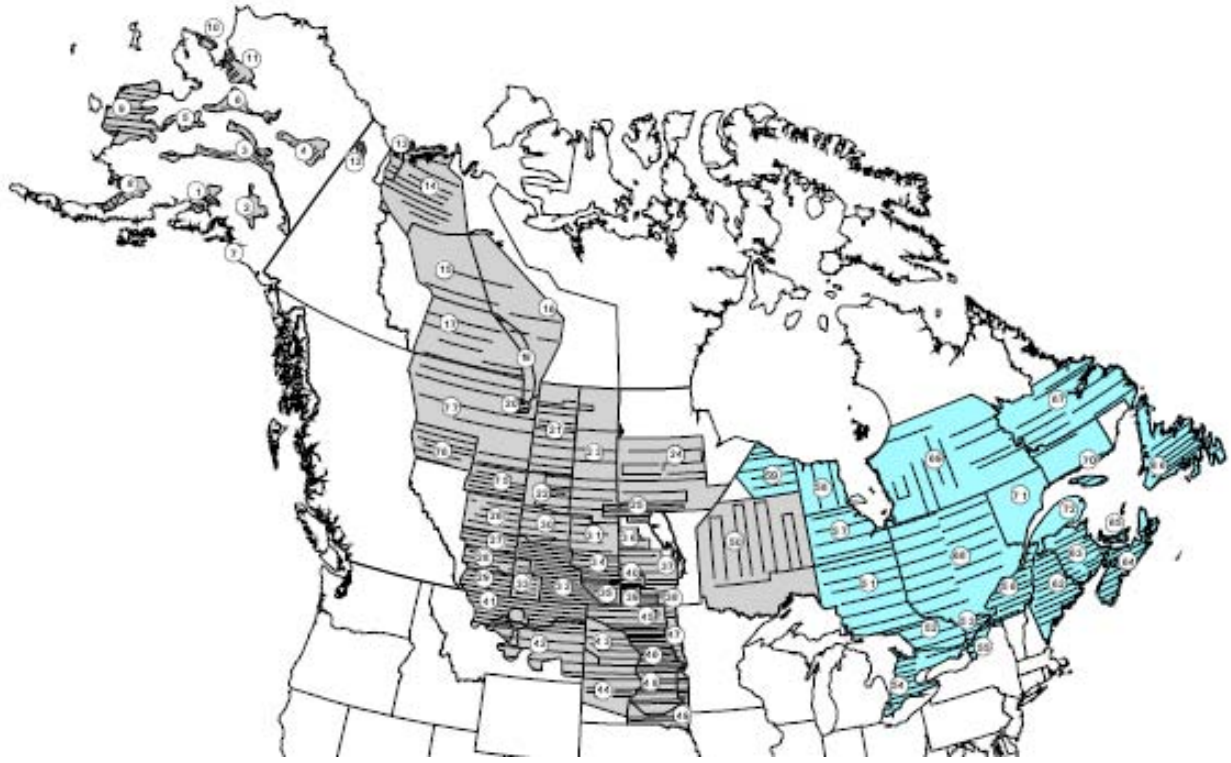

Figure 1. Strata and transects of the traditional CWS/USFWS Waterfowl Breeding Population and Habitat Survey (shaded grey) and the more recent USFWS Airplane Transect Survey (shaded blue). USFWS Airplane Transect Survey is described below.
Source: U.S. Fish and Wildlife Service (2007)

Eastern ecozones⁺

Additional surveys in eastern Canada were initiated independently by CWS and USFWS much later (around 1990). These include the USFWS Airplane Transect Survey (Figure 1), the CWS Boreal Helicopter Plot Survey, the Southern Ontario Waterfowl Ground Survey, and the Québec Basses Terres survey. Recently, considerable effort has been made to integrate these surveys into a single survey. The results of this integration were used to generate estimates for the "eastern ecozones⁺" (Atlantic Maritime, Mixedwood Plains, Newfoundland Boreal, Boreal Shield, and Taiga Shield) for this report. The four data sources used to derive population estimates for each eastern ecozone⁺ are summarized in Table 1 and described in more detail below.

Table 1. Sources of data used for waterfowl population estimates for the eastern ecozones⁺.

Data source	Site area (km^2)	# of sites	Eastern ecozones⁺				
			Taiga Shield	Boreal Shield	Mixedwood Plains	Atlantic Maritime	Nfld. Boreal
CWS Boreal Helicopter Plot	25	320		X		X	X
USFWS Airplane Transect	11.65/ segment	118	X	X	X	X	X
Québec Basses Terres*	4	125			X		
Southern Ontario Ground	0.64	349		X	X		

* The Québec Basses Terres survey covers areas in BCR 13 (Mixedwood Plains) and areas near Abitibi and Lac St Jean. Only the portion of the data in Mixedwood Plains was included in this analysis.

CWS Boreal Helicopter Plot Survey

The CWS Boreal Helicopter Survey is based on 5 km^2 plots run in a rotational design. The survey is run every year with each individual plot surveyed every five years in the rotational pattern. For this analysis, we included the boreal plots and some plots in the Appalachian region of Québec. In Ontario and Québec, the plots are placed systematically and can thus be partitioned into any necessary strata for analysis. In Nova Scotia, New Brunswick, and Newfoundland, the plots are not a systematic sample but did not require further stratification for this analysis because each plot is contained entirely within an individual ecozone⁺. In Labrador, there are plots in both the Taiga Shield and Boreal Shield ecozones⁺.

Surveys in some plots were initiated only recently and were therefore discarded for this analysis. These are:

- Newfoundland plot 49-57 started 2004 or later
- Labrador plot 43 run in 2003 and 2004
- Appalachian plot 1A12 started 2004

There was only one plot in BCR 13 (Mixedwood Plains). It was discarded from the analysis.

USFWS Airplane Transect Survey

The USFWS Airplane Transect Survey design partitions eastern Canada into 17 strata (Figure 2). Within each strata, the survey is based on a random selection of transects which are further subdivided into segments. The segments are 18 miles (~29 km) long and 0.25 miles (~0.4 km) wide. The number of segments within each transect varies. While surveys of most strata were initiated in 1996, Strata 51 to 54 were added after 1990, and Strata 58 and 59 were started in 2005 and 2006, respectively.

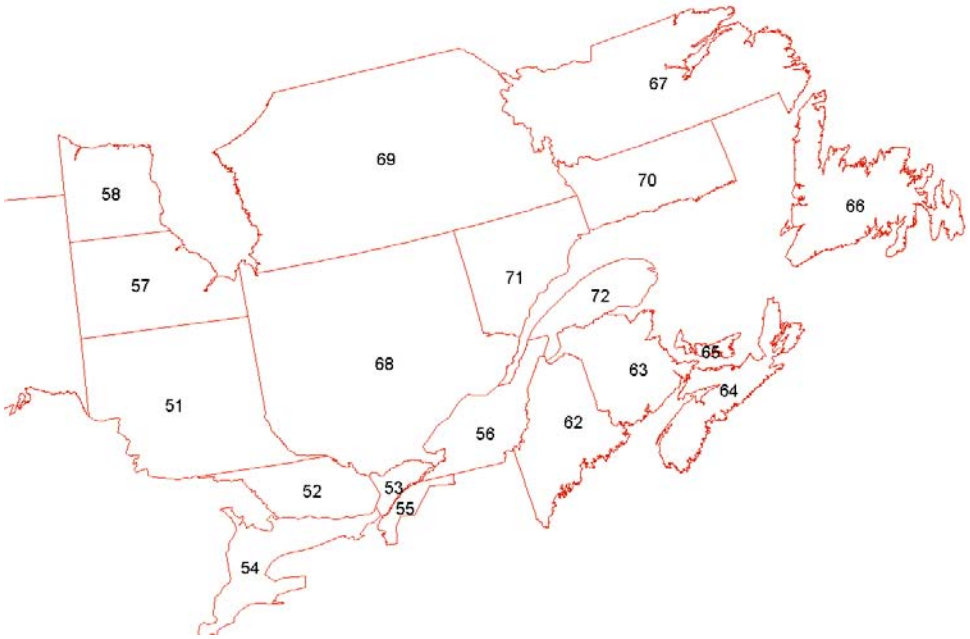

Figure 2. Strata for eastern USFWS Airplane Transect Surveys of waterfowl.
Source: U.S. Fish and Wildlife Service (2007)

The strata were developed to partition eastern Canada by province, grouping areas with similar habitat and areas which were practical for airplane transects. The resulting strata fit well into the ecozone+ framework, although some strata extend over more than one ecozone+. The relationship of the USFWS Airplane Transect Survey strata to ecozones+ is shown in Table 2. Individual transects also occasionally pass through different ecozones+. In these cases since the raw data on transect segments were available, we assigned each segment to an ecozone+ by comparing the segment length with the maps of ecozones+.

Table 2. Sampling intensity of USFWS Airplane Transect Survey, by stratum and ecozone+.

Ecozone+	Province	USFWS stratum	Area (a) (km^2)	Sample area (b) (km^2)	Extrapolation factor
Atlantic Maritime	QC	56 (part)	24,621 (c)	256.3	96
	QC	72	40,850	--	--
	NB	63	72,195	570.5	126
	NS	64	54,850	547.6	100
	PEI	65	5,762	58.2	99
Mixedwood Plains	ON	53	10,903	104.8	104
	ON	54	58,200	512.6	114
	QC	56 (part)	24,303 (c)	326.2	75
Newfoundland Boreal	NF	66	109,425	792.2	138
Boreal Shield	ON	51	198,544	885.4	224
	ON	52	53,475	372.8	143
	ON	57 (part)	(d)	0	--
	QC	68 (part)		1,386.4	252 (f)
	QC	69 (part)		69.9	370 (g)
	QC	70	84,393	244.6	345
	QC	71	87,529	--	--
	LB	67 (part)		116.5	267 (e)
Taiga Shield	QC	68 (part)		0	--
	QC	69 (part)		967.0	370 (g)
	LB	67 (part)		710.6	267 (e)

(a) stratum area used by USFWS

(b) sample area derived after standardizing the transects to include the same segments each year

(c) based on Québec total area for BCR 13 (24,303) and BCR 14 (65,471). The result is 6,681 km^2 less then USFWS area for stratum 56. This is possibly due to a portion of the Québec area being assigned to the shoreline survey or to differences between USFWS strata and ecozone+ boundaries.

(d) area of Boreal Shield ecozone+ in this USFWS stratum is small so area was deleted.

(e) USFWS stratum 67 area (221,221 km^2) divided by total sample area for all ecozones+

(f) USFWS stratum 68 area (364,739 km^2) divided by total sample area for all ecozones+

(g) USFWS stratum 69 area (405,979 km^2) divided by total sample area for all ecozones+

The sampling intensity for each stratum by ecozone+ was calculated as an extrapolation factor (Table 2). Strata within the same ecozone+ with similar extrapolation factors could be pooled for analysis purposes.

Comparable sample intensity for the CWS Boreal Helicopter Plot Survey is shown in Table 3.

Table 3. Sampling intensity for the CWS Boreal Helicopter Plot Survey for each USFWS stratum.

Ecozone[+]	Province	USFWS stratum	Area (a) (km^2)	Sample area (b) (km^2)	Extrapolation factor
Atlantic Maritime	QC	56 (part)	24,621 (c)	250	98
	QC	72	40,850	125	327
	NB	63	72,195	1,000	72
	NS	64	54,850	750	73
	PEI	65	5,762	--	
Mixedwood Plains	ON	53	10,903	--	
	ON	54	58,200	--	
	QC	56 (part)	24,303 (c)	--	
Newfoundland Boreal	NF	66	109,425	800	137
Boreal Shield	ON	51	198,544	850	234
	ON	52	53,475	125	428
	ON	57 (part)	(d)	--	
	QC	68 (part)	350,000 (f)	2,625	133
	QC	69 (part)		--	
	QC	70	84,393	400	210
	QC	71	87,529	675	130
	LB	67 (part)	31,000 (e)	175	177
Taiga Shield	QC	68 (part)		--	
	QC	69 (part)		--	
	LB	67 (part)	190,000 (e)	325	584

(a) stratum area used by USFWS

(b) total area of sample plots

(c) based on Québec total area for BCR 13 (24,303) and BCR 14 (65,471). This result is 6,681 km^2 less then USFWS area for stratum 56. This is possibly due to a portion of the Québec area being assigned to the shoreline survey or to differences between USFWS strata and ecozone[+] boundaries.

(d) The area of Boreal Shield in this USFWS stratum is small so area was deleted.

(e) USFWS stratum 67 area (221,221 km^2) apportioned across ecozones[+] by transect sample area

(f) USFWS stratum 68 area (364,739 km^2) apportioned across ecozones[+] by transect sample area

Québec Basses Terres

The Basses Terres Survey is based on 2 km^2 plots flown by helicopter. The survey is run in the St. Lawrence Lowlands, Abitibi, and Lac St. Jean regions. Most of the plots in the St. Lawrence Lowlands are in BCR 13 (Mixedwood Plains) but there are a few plots in BCR 12 (Boreal Shield). The BCR 12 plots were discarded for this analysis. The surveys in the Abitibi and Lac St-Jean regions were also discarded because they would need to be treated as new strata and only cover a relatively small area.

Southern Ontario Waterfowl Ground Survey

The Southern Ontario Waterfowl Ground Survey is partitioned into two strata – high and low waterfowl density – and is based on 0.8 km^2 plots surveyed on the ground (http://www.on.ec.gc.ca/wildlife/wildspace/project.cfm?HoldID=I28&Lang=e). The survey was initiated in 1974 and was run approximately every three years. Recently, the survey was changed to a rotating design with approximately one third of the plots run each year.

The stratum areas within each Bird Conservation Region (BCR) and the assignment of plots to BCRs are known and were used to assign the data to the Boreal Shield and Mixedwood Plains ecozones[+]. Because it is difficult to use this stratification with that used by the USFWS Airplane Transect Survey, only data from the Southern Ontario Waterfowl Ground Survey were used for southern Ontario.

Summary of data availability

Table 4 summarizes data availability for each ecozone[+] (organized by USFWS stratum) from all surveys from 1970 to 2006.

Table 4. Available population estimates from all surveys for each stratum by year for each ecozone[+].

Stratum	1970-89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06
Atlantic Maritime																		
56AM		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
72		X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X
63*					X	X	X	X	X	X	X	X	X	X	X	X	X	X
64		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
65 (dropped for this report)								X	X	X	X	X	X	X	X	X	X	X
Data used in this report					**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Newfoundland Boreal																		
66								X	X	X	X	X	X	X	X	X	X	X
Data used in this report								**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Mixedwood Plains																		
5354		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
56MW		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Data used in this report		**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Boreal Shield																		
51		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
52		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
68BS		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
69BS (dropped in report)										X	X	X	X	X	X	X	X	X
70		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
71		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
67BS		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
24	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
36	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X
Data used in this report		**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**		**X**	**X**	**X**	**X**
Taiga Shield																		
69TS										X	X	X	X	X	X	X	X	X
67TS		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
16	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
18	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Data used in this report										**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Taiga Plains																		
15	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
17	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Data used in this report	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Boreal Plains																		
20	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
22	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
25	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
75 (dropped for this report)								X	X	X	X	X	X	X	X	X	X	X
76 (dropped for this report)								X	X	X	X	X	X	X	X	X	X	X
Data used in this report	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Prairies																		
26	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
27	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
28	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
29	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
32	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
33	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
34	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
35	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
38	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X
39	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
40	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Data used in this report	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**		**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**

* data from New Brunswick for 1990-1992 missing due to observer change.

Data Analysis

Western ecozones+

The analysis for the western ecozones+ was straight forward and used only the CWS/USFWS Waterfowl Breeding Population and Habitat Survey.We added the reported population estimates for all stratums within each ecozone+ and then calculated: 1) the annual averages by decade; 2) the percent change between the first and last decade; and 3) the trend from a simple regression over the period of the survey. Calculation of the regression line used estimates converted to the log scale. The standard error (SE) for the log of the index for each year was approximated from the reported SE using a Taylor approximation. The SE of the trend was calculated as a weighted combination of the SE for individual years. In cases where the index was zero, the SE of the log was also set to zero. If a species was not seen in an ecozone+ in a given year but there had been surveys run in each stratum then the annual index was set to zero. To accommodate this in the log-transform, we set the value to one half the smallest non-zero count for any year for the trend calculation.

The trend in log scale was calculated as:

$$b = \frac{\sum_j (x_j - \bar{x}) I_j}{\sum_j (x_j - \bar{x})^2}$$

Where I_j = natural log of the annual Index for year j

x_j = jth year

This slope was converted to other variables:

1) annual percentage change: $APC = 100(exp(b) - 1)$
2) total percentage change over a time period of k years: $TPC = 100\left(\exp(bk) - 1\right)$

Eastern ecozones+

The analysis for eastern ecozones+ was carried out using a custom written C++ program based on the assumption that all surveys in the same strata were measuring the same population and thus year to year differences were consistent among different surveys. A Poisson model was fitted separately for each stratum, taking into account the effects of site and year, with a log link function. The site area was used as an offset term in the model, so that site effects were measures of population density. The average observed density for each survey by stratum combination was estimated from the fitted model. The relative detection rates among surveys were then estimated by designating certain surveys as effective complete counts and assuming other surveys in the same strata detected a proportion of the birds observed. (See Calculation of relative detection rates section on page 10 for further explanation of relative densities and detection rates). The site effects from the Poisson model were then adjusted by the relative detection rate and a stratum by year population density was calculated for each stratum as a

weighted average across surveys, with the weighting based on the among site variability within each survey.

Annual indices and densities were calculated for each eastern ecozone[+] by summing across all strata within the ecozone[+]. If estimates were not available for all strata within the ecozone[+] in an individual year, then no estimate was calculated for the ecozone[+]. The individual strata were summed to provide an overall eastern Canada estimate. A simple regression of the log annual index against year was also calculated at the stratum, ecozone[+], and eastern Canada level. The SE of all estimates was calculated using a jackknife procedure.

Stratification

The USFWS Airplane Transect Survey dictated much of the stratification for the analysis; however, it was necessary to further partition these strata into smaller areas in order to match the ecozones[+].

- Stratum 56 is partitioned into 56AM and 56MW
- Stratum 67 is partitioned into 67BS and 67TS
- Stratum 68 is partitioned into 68BS, 68TS and 68HP (the latter was not used in this analysis)
- Stratum 69 is partitioned into 69BS and 69HP (the latter was not used in this analysis)
- There were no segments in 69TS and the potential stratum was discarded
- Strata 53 and 54 had the same sampling intensity and were merged.
- Stratum 58 was only run in 2005 and 2006 and was discarded.

The Southern Ontario Waterfowl Ground Survey analysis is based on two strata (Table 5) Stratum 5354 was replaced with strata 13HI and 13LO, while stratum 52 was replaced with strata 12HI and 12LO. These new strata have somewhat different areas than the original strata. This is probably due to the USFWS strata not being aligned with the BCRs or ecozones[+].

Table 5. Availability and assignment of all survey strata to each ecozone[+].

Ecozone[+]	USFWS Stratum	Province	Area (km^2)	Data Source			
				USFWS Transect	CWS Plot	Southern Ontario	Basses Terres
Atlantic Maritime	56AM	QC	24,621	X	X		
	72	QC	40,850		X		
	63	NB	72,195	X	X		
	64	NS	54,850	X	X		
	65	PEI	5,672	X			
Mixedwood Plains	13HI	ON	51,353		(b)	X	
	13LO	ON	26,890			X	
	56MW	QC	24,303	X			X
Newfoundland Boreal	66	NF	109,425	X	X		
Boreal Shield	51	ON	198,544	X			
	12HI	ON	14,376			X	
	12LO	ON	34,095			X	
	68BS	QC	350,000 (a)	X	X		
	69BS	QC	26,000 (a)	X			
	70	QC	84,393	X	X		
	71	QC	87,529		X		
	67BS	LB	31,000 (a)	X	X		
Taiga Shield	68TS	QC	0 (a)	(c)			
	69TS	QC	358,500 (a)	X			
	67TS	LB	31,000 (a)	X			

(a) area estimated as proportional to sampled area by transects;
(b) discarded from analysis (only one plot);
(c) no segments

Available estimates

Table 5 shows the availability of data by data source, stratum, and ecozone[+]. In most cases, there are multiple strata within an ecozone[+]. A total population estimate can only be calculated for a given year for an ecozone[+] if data from all the individual strata within the ecozone[+] are available. If some strata are missing, then the ecozone[+]-wide estimate was not calculated for that year. For individual species there may be few available estimates if the species was never recorded in a stratum by year combination.

Calculation of relative detection rates

The different survey platforms detect different proportions of the population. In order to combine the different platforms one survey was selected as the standard and estimates from the other survey were scaled to provide the same density. This scaling factor is the relative detection rate. The relative detection rate was estimated through maximum likelihood for all strata and years where both surveys were run. The survey with the highest observed density was used as the standard survey.

In the Mixedwood Plains, the Basse Terres Survey was used as the standard because it provided the highest observed density. In all other ecozones+, the eastern waterfowl survey was used as the standard survey. The USFWS transect survey was used as the standard survey for Canada Geese. While the CWS Helicopter Plot survey and Basse-Terres surveys were used as the standard for all other species.

The estimated relative detection rates are shown in Table 6. Table 6b shows the results for the analysis in which the Basses Terres data were assumed to be complete for stratum 56MW and the combination of CWS Helicopter Plot and USFWS Airplane Transect data were assumed to be complete for all other strata.

Table 6. Estimated relative detection rates.

a) USFWS Airplane Transect Survey relative detection rates

Species	Relative detection rate	Standard Error (SE)
Mallard	0.43	0.037
American Black Duck	0.34	0.036
Ring-necked Duck	0.23	0.023

b) Relative detection rates for CWS Helicopter Plot/USFWS Airplane Transect and USFWS Airplane Transect/Basses Terres surveys

Species	CWS Plot/Transect		Transect/Basses Terres	
	Relative detection rate	SE	Relative detection rate	SE
Canada Goose	0.62	0.18	0.11	0.024

Species Selection

Species selection for each ecozone+ was determined using two criteria: 1) data availability, defined as the ability of the surveys to provide reliable estimates for a decade to derive trends; and 2) the importance of a given species to the ecozone+, defined by the priority species of the North American Waterfowl Management Plan (NAWMP) implementation plans and from the perspective of significance to biodiversity.

Data Availability

The USFWS Airplane Transect Survey limits which species can be analyzed. The standard operating procedures for this survey doesn't differentiate many species. For example, mergansers, scaup, and scoters are reported as species groups, not to the species level.

For the eastern ecozones+, a set of 15 species from the USFWS Airplane Transect Survey were initially examined as potential species to highlight. Six species, Northern Shoveler, Redhead, Canvasback, Long-tailed Duck, Ruddy Duck, and American Coot are observed too infrequently for an effective trend analysis to be run and were therefore not used in the analysis for this report.

Priority species

The NAWMP partners, including the Science Support Team, Joint Ventures, and biologists from Canada, Mexico, and the United States, have prioritized species based on socioeconomic importance and population trend or vulnerability to population decline (North American Waterfowl Management Plan, 2004). A detailed description of the NAWMP prioritization process can be found in NAWMP Plan Committee (2004) and in various implementation plans for respective Joint Ventures. The NAWMP priorities were identified at continental and regional scales. At the continental scale two main criteria were used, continental population trends and importance to harvest. Criteria used at the regional scale include, relative density during breeding and non-breeding periods of the Waterfowl Conservation Region[6] (compared to other Waterfowl Conservation Regions) and threat to the habitat (North American Waterfowl Management Plan, 2004).

Species selection for this report were based primarily on the importance of an ecozone[+] to a given species for breeding since only surveys from the breeding period were used for this analysis.

RESULTS BY ECOZONE[+]

Atlantic Maritime Ecozone[+]

Both the CWS and USFWS monitor waterfowl populations in the Atlantic Maritime Ecozone[+] and results from an analysis which integrated observations from both surveys were used for this report. The selection of species was based on a combination of the historical and/or current importance of the species to this ecozone[+] and data availability.

Trends indicate either stable or increasing populations (Table 7 and Figure 3). The American Black Duck, the most abundance duck species in the ecozone[+], has been the focus of special conservation effort because the population in the United States declined by almost 50% between 1955 and 1985 (Lepage and Bordage, 2003). This prompted the creation of the Black Duck Joint Venture under the NAWMP to improve knowledge of Black Ducks and guide conservation and management decisions. Logging, hydroelectric development, transmission line construction, agriculture, urbanization, and other industrial developments threaten American Black Duck breeding and staging habitats (Lepage and Bordage, 2003). A more recent threat is competition for habitat, particularly in agricultural areas, with the Mallard (Petrie et al., 2000), which has been expanding its breeding range and increasing in abundance throughout eastern North

[6] The regional scale was tailored to ecological regions with relatively homogeneous waterfowl communities, habitats, species-habitat relationships, and threats to habitats. Consequently, "Waterfowl Conservation Regions" were created for NAWMP's geographic units. These Waterfowl Conservation Regions are essentially subdivisions of Bird Conservation Regions (BCR), which have been widely accepted in the avian conservation and management community as planning units. Not surprisingly, BCR delineations (or combination of several BCRs) closely match those of ecozones[+] as both systems are variations of the national ecological classification system.

America (Lepage and Bordage, 2003). Habitat availability and quality may not be limiting for dabbling ducks. Mallards and Black Ducks nesting in a heavily farmed area in midwestern New Brunswick were found to have breeding vital rates (such as nest success, hen success, and duckling survival) above the level thought necessary to maintain population size (Petrie et al., 2000). The recent increases and stabilization of the American Black Duck population in the Atlantic Maritime may be due to changes in management practices (such as, increased hunting restrictions in both Canada and the United States) (Longcore et al., 2000).

Table 7. Abundance trends for selected breeding waterfowl species in the Atlantic Maritime Ecozone[+].

Species	Nesting habitat	Trend (%/yr)	P	Annual Index (in 1000s)		
				1990s	2000s	% change
Mallard	Ground	30.084	*	2.3	4.6	98.1
American Black Duck	Ground	2.214		57.7	63.7	10.5
Green-winged Teal	Ground	5.892	n	8.4	11.7	38
Ring-necked Duck	Overwater	6.479	*	21.2	32.3	52.2
Canada Goose		22.502	*	1.1	3.6	244.3

P is the statistical significance, * indicates P<0.05; n indicates 0.05<P<0.1; no value indicates not significant

Source: data from USFWS Airplane Transect Survey and CWS Boreal Helicopter Plot Survey

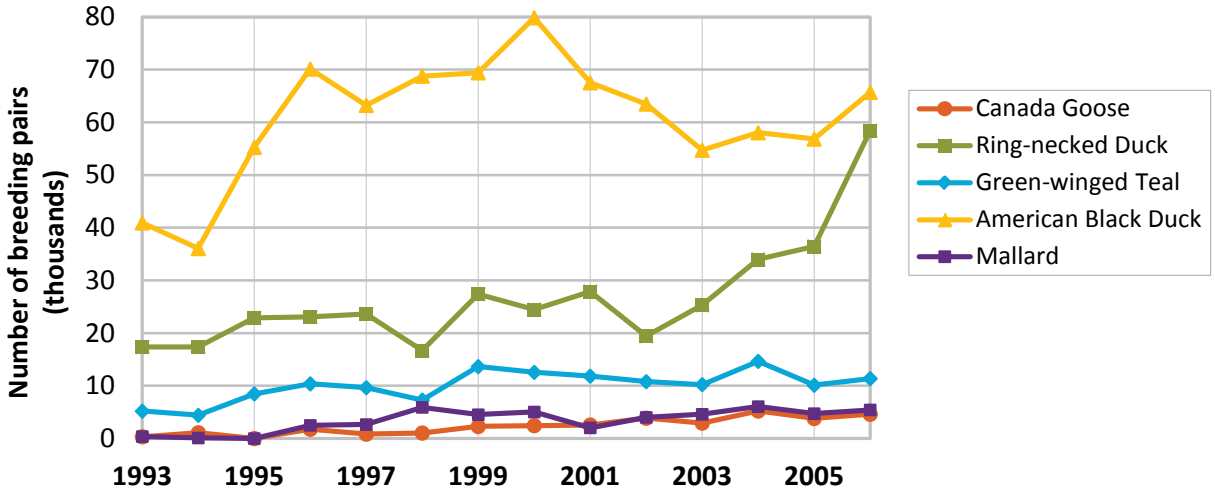

Figure 3. Population trends for Canada Goose, selected diving ducks (Ring-necked Duck), and dabbling ducks (Green-winged Teal, American Black Duck, and Mallard) in the Atlantic Maritime Ecozone[+], 1993-2006.

Source: data from USFWS Airplane Transect Survey and CWS Boreal Helicopter Plot Survey

Green-winged Teal and Ring-neck Duck populations also increased since the 1990s although the reasons remain unknown. Increases in the Canada Goose population are consistent with other regions within the goose's temperate breeding range (Dickson, 2000).

Although not well captured by the monitoring surveys used in this analysis, Barrow's Goldeneye (*Bucephala islandica*) and Harlequin Ducks have been assessed as Species of Special

Concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC, 2006). The Barrow's Goldeneye winters along the coast of this ecozone+ (Eadie et al., 2000), while the Harlequin Duck breeds along the north shore of the Gulf of St. Lawrence, the Gaspé Peninsula, and northern New Brunswick, and many winter on the east and south coast of New Brunswick. Oil spills and sediment contamination are threats to survival of these species in their wintering habitat (COSEWIC, 2006). In addition, some previously fast-flowing streams where Harlequin Ducks nest have been altered by hydro and mining projects (COSEWIC, 2006).

The Atlantic Maritime has many coastal areas where large numbers of waterfowl traditionally congregate during the spring and fall migration (U.S. Fish and Wildlife Service, 2009), and many waterfowl also winter in this ecozone+. Recent milder winters with longer ice free periods have resulted in an increase in wintering populations and a potential increase in the residency time of waterfowl during migration (EHJV, 2007b).

Mixedwood Plains Ecozone+

The CWS monitors waterfowl populations in the Mixedwood Plains Ecozone+ (Dennis, 1974). Relative to other ecozones+, this is a moderately important region to waterfowl because it provides habitat during breeding, staging, and wintering. The selection of species was based on a combination of the historical and current importance of the species and data availability.

Results show different population trajectories among species (Table 8 and Figure 4). Between the 1990s and 2000s, Blue-winged Teal and American Black Duck declined considerably; Mallard remained stable; and Canada Goose increased substantially.

Table 8. Abundance trends for selected breeding waterfowl species in the Mixedwood Plains Ecozone+.

Species	Nesting habitat	Trend (%/yr)	Average Index (in 1000s)		
			1990s	2000s	% change
Blue-winged Teal	Ground	N/A	6.2	3.8	-37.8
American Black Duck	Ground	N/A	11.4	5.9	-48.2
Mallard	Ground	N/A	92.6	95.0	2.5
Canada Goose	Ground	N/A	30.7	57.0	85.7

Source: data from the Southern Ontario Waterfowl Ground Survey

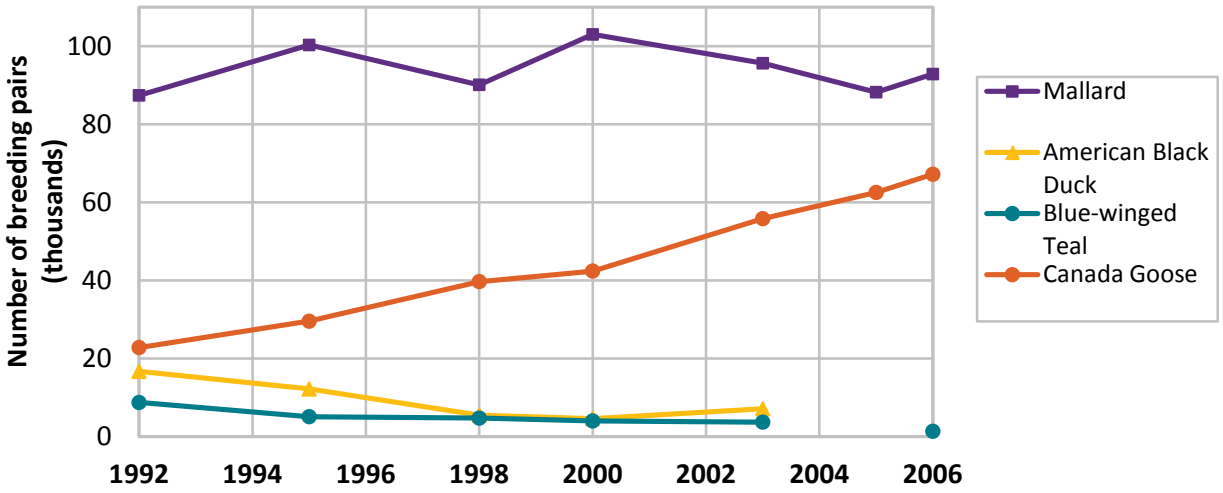

Figure 4. Population trends for selected breeding dabbling ducks (Mallard, American Black Duck, and Blue-winged Teal) and Canada Goose in the Mixedwood Plains Ecozone⁺, 1992-2006.
Source: data from the Southern Ontario Waterfowl Ground Survey

The Blue-winged Teal has significantly declined to the point where it is rarely detected during surveys. This decline is likely the result of fewer wetlands on the landscape. Shifts in agricultural practices (for example, conversion of pasture land to cropland and tile drainage or natural succession of marginal farmland to forest) has resulted in a decrease in seasonal wetlands and, to a lesser extent, semi-permanent wetlands (EHJV, 2007c).

The Mallard population remained stable from the 1990s to 2000s. However, prior to the 1950s, the Mallard was likely not found in Ontario and it has become the most abundant and widely distributed duck species in the province (Zimmerling, 2007).

Once one of the most abundant breeding ducks in the Mixedwood Plains Ecozone⁺, the American Black Duck has declined since the 1960s (Ross, 2007). This led to its designation as a species of concern under NAWMP. Reasons for the decline are not clear but potential causes include loss of habitat and displacement as a result of interspecific competition and introgression with the Mallard which, as noted above, dramatically increased in numbers (EHJV, 2007c).

The temperate breeding Canada Goose population has increased substantially in the ecozone⁺ and similarly throughout the rest of its breeding range (Canadian Wildlife Service Waterfowl Committee, 2008). The species easily adapts to a variety of habitats, including farmland and urban areas. This has allowed them to take advantage of the conversion of native habitat to cultivated land and urban areas, benefitting from increased cereal grain, planted forage, and turf grass food sources (Mowbray et al., 2002).

Newfoundland Boreal Ecozone[+]

Waterfowl populations in the Newfoundland Boreal have been monitored jointly by CWS and USFWS since 1990. Compared to other ecozones[+], the Newfoundland Boreal is moderately important for breeding waterfowl. Inland and coastal wetlands in this ecozone[+] are used by waterfowl for breeding and during the spring and fall migration (U.S. Fish and Wildlife Service, 2009). The Harlequin Duck (*Histrionicus histrionicus*), assessed as a Species of Special Concern by Committee on the Status of Endangered Wildlife in Canada (COSEWIC, 2006), is known to moult along the Newfoundland coast (Gilliland et al., 2002) and American Black Duck (*Anas rubripes*), King Eider (*Somateria spectabilis*), Long-tailed Duck (*Clangula hyemalis*), and especially, Common Eider (*Somateria mollissima borealis/dresseri*) are known to regularly over-winter in the open waters surrounding Newfoundland (Bellrose, 1980).

Population trends of selected species reveal that waterfowl populations in this ecozone[+] were generally stable or increasing between the 1990s and 2000s (Table 9 and Figure 5). Newfoundland lacks several nest predators, including the striped skunk (*Mephotos mephitis* Schreger) and raccoon (*Procyon lotor*), that are common in other regions (Thompson et al., 2008). Inland nesting habitat in particular does not appear to be limiting except for the cavity nesting Common Goldeneye *(Bucephala clangula)* (EHJV, 2007a). Reasons for the declining trend of Green-winged Teal (*Anas carolinensis*) remain unclear.

Table 9. Abundance trends for selected breeding waterfowl species in the Newfoundland Boreal.

Species	Nesting habitat	Trend (%/yr)	P	Annual Index (in 1000s)		
				1990s	2000s	% change
American Black Duck	Ground	1.988	n	15.9	19.4	21.9
Green-winged Teal	Ground	0.805		4.1	3.6	-11.6
Ring-necked Duck	Overwater	3.2	*	11.5	19.5	69.3
Common Goldeneye	Cavity	3.922		4.9	7.1	46.1
Canada Goose		3.532	*	11.5	13.1	13.9

P is the statistical significance: * indicates P<0.05; n indicates 0.05<P<0.1; no value indicates not significant

Source: data from USFWS Airplane Transect Survey and the CWS Boreal Helicopter Plot Survey

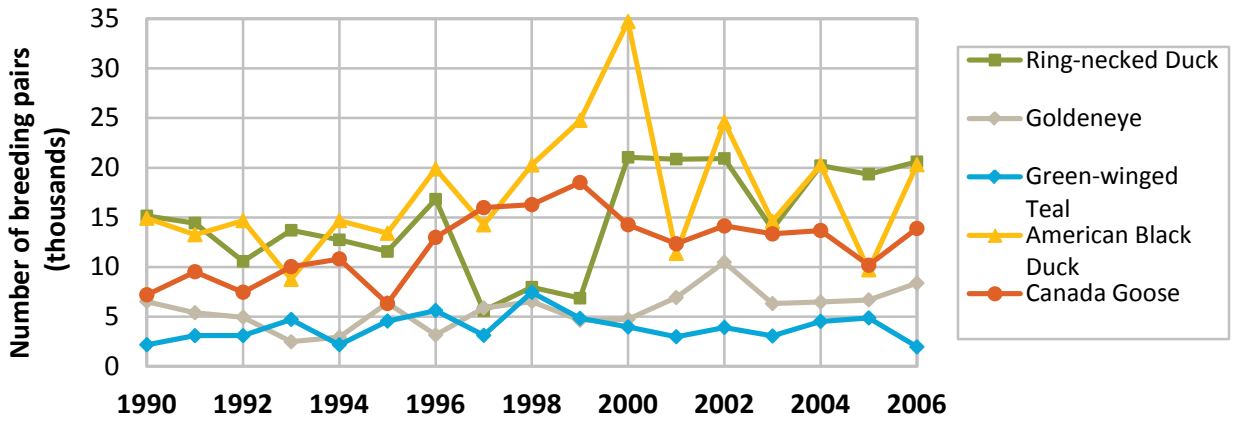

Figure 5. Population trends for selected diving ducks (Ring-necked Duck and goldeneye), dabbling ducks (Green-winged Teal and American Black Duck), and Canada Goose in the Newfoundland Boreal Ecozone⁺, 1990-2006.
Source: data from USFWS Airplane Transect Survey and CWS Boreal Helicopter Plot Survey

Boreal Shield Ecozone⁺

Although waterfowl densities are relatively low in the Boreal Shield Ecozone⁺, it is of considerable importance to waterfowl due to its large area. Both breeding and staging waterfowl from the Atlantic, Mississippi, and Central Migratory Flyways occur in this ecozone⁺ (U.S. Fish and Wildlife Service, 2009). There are a variety of data sources from which breeding waterfowl population trends can be generated in this area. In order to maximize data use, this ecozone⁺ was divided into eastern and western sections, using a division of approximately 86°E. The western area is covered by the CWS/USFWS Waterfowl Breeding Population and Habitat Survey and the eastern area is covered by the USFWS Airplane Transect Survey and the CWS Boreal Helicopter Plot Survey.

In the western portion of the ecozone⁺, population trends of American Wigeon, and scaup (combined Lesser Scaup (*Aythya affinis*) and Greater Scaup (*A. marila*)) indicate declines over the survey period, particularly over the last decade (Table 10 and Figure 6*).* These declining trends were also found in neighbouring ecozones⁺ (Boreal Plains, Taiga Plains, Taiga Shield, and Prairies) suggesting common factors that operate within or beyond the breeding areas. Although little research has been carried out on American Wigeon, some research has been testing various hypotheses for the scaup decline (Austin et al., 2000).

Table 10. Abundance trends for selected breeding waterfowl species in the western portion of the Boreal Shield Ecozone[+].

Species	Nesting habitat	Trend (%/yr)	P	Annual Index (in 1000s)				
				1970s	1980s	1990s	2000s	% change
Ring-necked Duck	Overwater	3.463	*	153.5	199.9	337.7	433.9	182.7
Bufflehead	Cavity	0.591		64	55.7	73.6	79	23.5
Goldeneye (Common and Barrow's)	Cavity	1.545	*	170	174.6	268.7	272.3	60.2
American Wigeon	Ground	-2.043	*	152.1	127.8	115.6	79.6	-47.6
Scaup (Lesser and Greater)	Ground	-1.919	*	236.7	202.8	200.8	133.7	-43.5
Scoter (White-winged and Surf)	Ground	-0.998		50.7	56.6	47.1	44.1	-13.1
Mallard	Ground	-0.452		635.8	599.8	649.4	555.3	-12.7
Green-winged Teal	Ground	1.794	*	101	101.8	152.2	140.6	39.2
Canada Goose	Ground	3.655	*	68.6	100	130.7	165.1	140.6
Pond		-1.121	*	84.6	57.5	60.2	52.3	-38.2

P is the statistical significance: * indicates P<0.05; no value indicates not significant

Source: data from CWS/USFWS Waterfowl Breeding Population and Habitat Survey

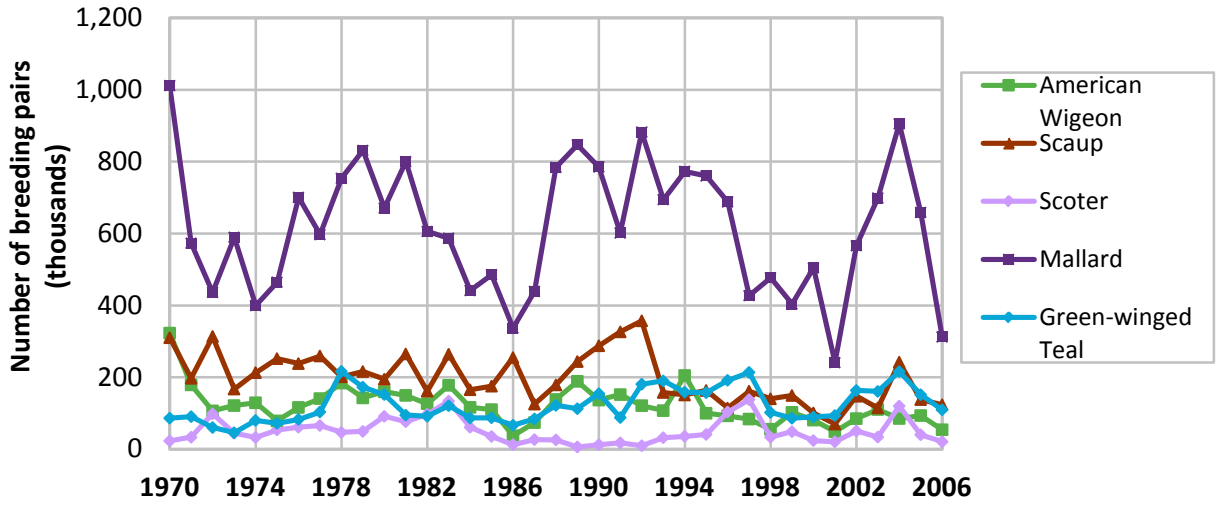

Figure 6. Population trends for breeding American Wigeon, scaup, scoter, Mallard, and Green-winged Teal in the western Boreal Shield Ecozone[+], 1970-2006.
Source: data from CWS/USFWS Waterfowl Breeding Population and Habitat Survey

The population trends of scoters (combined White-winged (*Melanitta fusca*) and Surf (*M. perspicillata*), Buffleheads (*Bucephala albeola*), and Mallards have remained stable over the long term despite considerable year-to-year variation. This is a pattern common to waterfowl (Figure 6 and Figure 7).

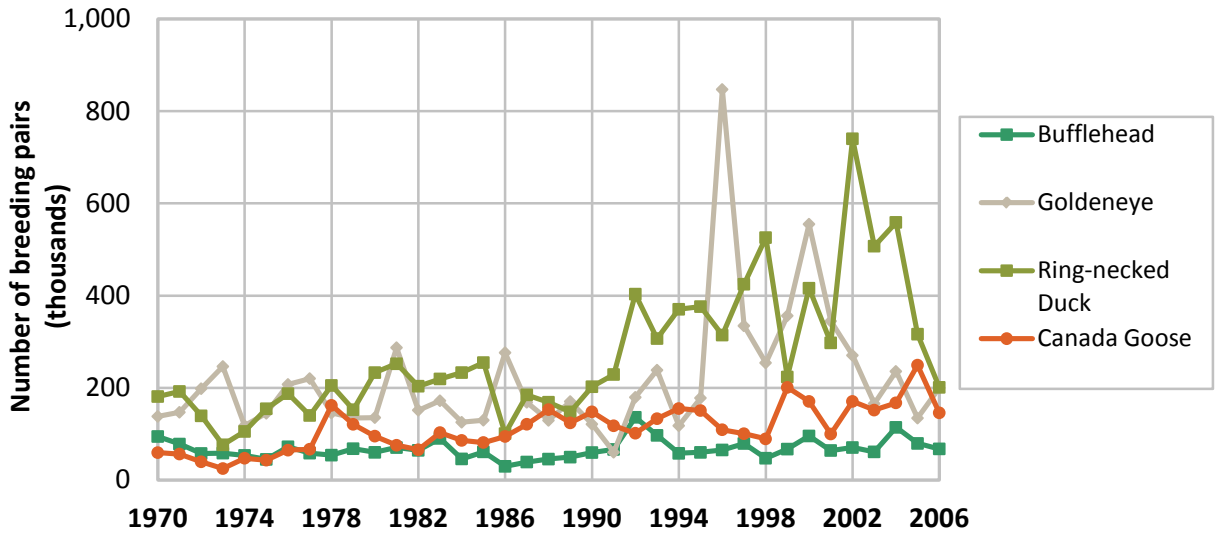

Figure 7. Population trends for breeding Bufflehead, goldeneye, Ring-necked Duck, and Canada Goose in the western Boreal Shield Ecozone[+], 1970-2006.
Source: data from CWS/USFWS Waterfowl Breeding Population and Habitat Survey

Some species experienced an increase in population although the population trajectories differed among species and causes for these trends remain unclear. For example, the Green-winged Teal experienced a gradual increase with considerable annual variation, whereas the goldeneye (combined Common and Barrow's) population was stable for several years before it substantially increased for a seven year period starting in the mid-1990s. It has recently dropped back to its historical level, however. The cause of the increase of the Ring-necked Duck population across its breeding range remains unclear as it considerably overlaps with scaup and shares many life history traits (such as, wintering area, breeding area and season, and diet) (De Vink et al., 2008).

Canada Goose populations are showing increasing trends in both the eastern and western regions of the Boreal Shield Ecozone[+] (Table 10 and Table 11). This is a similar trend to those seen in other ecozones[+] that have temperate nesting breeding populations. Temperate nesting Canada Geese have likely benefited from the conversion of forest to cultivated land and urban areas, taking advantage of planted forage and turf grass as food sources (Mowbray et al., 2002).

Table 11. Abundance trends for selected breeding waterfowl species in the eastern portion of the Boreal Shield Ecozone[+].

Species	Nesting habitat	Trend (%/yr)	P	Annual Index (in 1000s)		
				1990s	2000s	% change
Ring-necked Duck	Overwater	2.395	*	95.7	119.7	25
Bufflehead	Cavity	-2.169		9.6	9	-6.2
Goldeneye (Common and Barrow's)	Cavity	2.155		86.7	107.1	23.5
Green-winged Teal	Ground	-1.654		34	32.2	-5.1
American Black Duck	Ground	1.315	*	141.6	162.4	14.7
Mallard	Ground	3.896	*	64.4	88.2	36.8
Canada Goose		6.746	*	27.1	47.4	75.4

P is the statistical significance: * indicates P<0.05; no value indicates not significant

Source: data from USFWS Airplane Transect Survey, CWS Boreal Helicopter Plot Survey, and Southern Ontario Waterfowl Ground Survey

Some of the trends in the eastern Boreal Shield are similar to those observed in the west (Figure 8 and Figure 9). Ring-necked Ducks increased in the east, while other species remained stable (Bufflehead, Green-winged Teal, Mallard). The population trend for goldeneyes (combined Common and Barrow's) slightly increased, although not significantly. The eastern population of Barrow's Goldeneye was assessed by COSEWIC as Special Concern in November 2000 (COSEWIC, 2006). These cavity-nesting ducks are found breeding in eastern Québec and wintering along the Gulf of St. Lawrence and the St. Lawrence Estuary (Eadie et al., 2000). Potential threats to this species includes accumulation of heavy metals in prey items, recreational development on breeding lakes, loss of nesting habitat due to timber harvest (especially large trees for nesting), and fish introductions (Eadie et al., 2000). Timber harvest can destroy nests, reduce the number of potential nest sites, expose young to predation, and increase disturbance by making lakes more accessible (COSEWIC, 2006). Some lakes that were originally fishless have been stocked with brook trout in some areas, and there are indications that the fish presence could reduce the quality of lakes for Barrow's Goldeneye (COSEWIC, 2006).

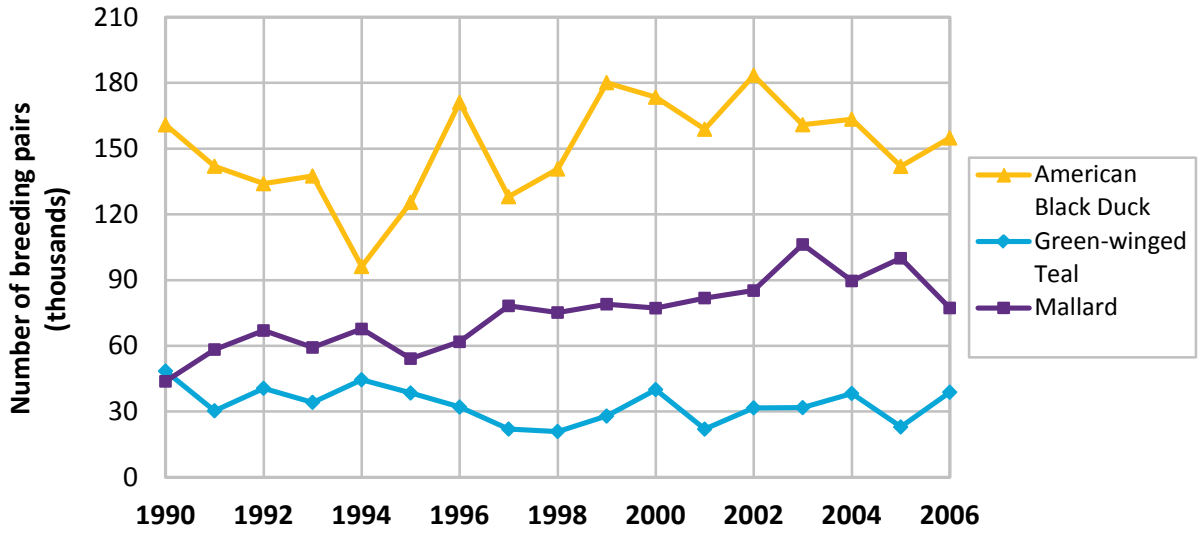

Figure 8. Population trends for selected breeding dabbling ducks (American Black Duck, Green-winged Teal, and Mallard) in the eastern Boreal Shield Ecozone[+], 1990-2006.
Source: data from USFWS Airplane Transect Survey, CWS Boreal Helicopter Plot Survey, and the Southern Ontario Waterfowl Ground Survey

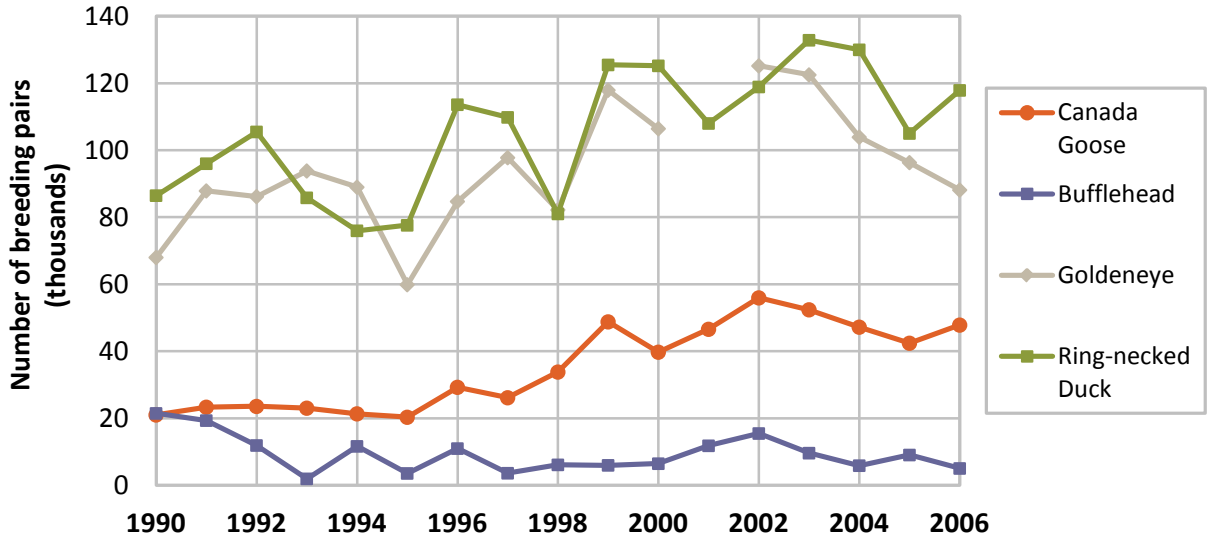

Figure 9. Population trends for Canada Goose and selected diving ducks (Bufflehead, goldeneye (Common and Barrow's), and Ring-necked Duck) in the eastern Boreal Shield Ecozone[+], 1990-2006.
Source: data from USFWS Airplane Transect Survey, CWS Boreal Helicopter Plot Survey, and the Southern Ontario Waterfowl Ground Survey

The Mallard population has increased in the eastern Boreal Shield (Figure 8), a trend common to other eastern ecozones[+] and consistent with its range expansion in the east. The American Black Duck has been the focus of special conservation effort because the population in the United States decreased by almost 50% between 1955 and 1985 (Lepage and Bordage, 2003). This prompted the creation of the Black Duck Joint Venture under NAWMP to improve

knowledge and guide conservation and management decisions. Logging, hydroelectric development, transmission line construction, agriculture, urbanization, and industrial development may threaten American Black Duck breeding and staging habitats in Québec (Lepage and Bordage, 2003). In addition, in southern Québec, the American Black Duck has recently had to compete for habitat with the Mallard which has been expanding its breeding range in this region (Lepage and Bordage, 2003). The recent increases in the American Black Duck population in the eastern Boreal Shield may be due to changes in management practices (such as increased hunting restrictions in both Canada and the United States) (Longcore et al., 2000).

Taiga Shield Ecozone^{+}

There are a variety of data sources from which breeding waterfowl population trends can be generated in the Taiga Shield Ecozone^{+}. In order to maximize data use, this ecozone^{+} was divided into eastern and western portions, with Hudson Bay being the natural divider. The best data set on waterfowl species distribution, composition, and abundance in the eastern Taiga Shield comes from the joint CWS/USFWS Waterfowl Breeding Population and Habitat Surveys that were established in 1990. The western area is best covered by surveys initiated in 1955 by the CWS/USFWS although this survey only covers the area west of longitude 110^{o}E, adjacent to the Taiga Plains Ecozone^{+}. The selection of species is based on a combination of the historical and current importance of the species, and data availability.

Scaup (combined Lesser and Greater), American Wigeon, and scoter (combined White-winged and Surf) populations showed declining trends from the 1970s to 2000s (Table 12 and Figure 10). These declining trends were also found in neighbouring ecozones^{+} (Boreal Plains, Taiga Plains, Boreal Shield, and Prairie) suggesting common factors that operate either within or beyond the breeding areas. Although little research has been carried out on the American Wigeon, research has been testing various hypotheses for the scoter and, in particular, the scaup decline (Austin et al., 2000). Austin et al. (2000) suggested that contaminants, lower female survival, and reduced recruitment due to changes in food resources or breeding ground habitats were possible factors contributing to the decline in continental scaup populations. DeVink et al. (2008) found no support for a relationship between declines in Lesser Scaup and White-winged Scoter populations and selenium contamination. Specifically, they found spring selenium levels were low in Ring-necked Ducks and Lesser Scaup, and elevated levels detected in White-winged Scoters did not appear to be detrimental to female body condition or breeding propensity. Estimated female survival rates during the breeding season are similar throughout the Lesser Scaup breeding range (Koons and Rotella, 2003; Rotella et al., 2003; Brook and Clark, 2005). Similarly, body condition of Lesser Scaup breeding near Yellowknife, Northwest Territories, are relatively similar to that of Ring-necked Duck and to historical levels for Lesser Scaup. This provides evidence against decreases in spring female body condition as the primary cause for decreasing population trends in this species (De Vink et al., 2008), but see Anteau and Afton (2009). Lesser Scaup, White-winged Scoter, and American Wigeon are relatively late nesters (Brown and Fredrickson, 1997; Austin et al., 1998; Mowbray, 1999). De Vink et al. (2008) suggest that if there is a dependence on photoperiod as a breeding cue then a possible mismatch

between timing of nesting (and therefore peak hen and duckling food requirements) and food availability may be occurring -- the availability of their invertebrate food source may be shifting with changing temperatures resulting in decreased hen and duckling survival. However, since very few studies have been conducted in the eastern Taiga Shield the reasons for these declining waterfowl population trends are not well understood.

Table 12. Abundance trends for selected breeding waterfowl species in the western portion of the Taiga Shield Ecozone[+].

Species	Nesting habitat	Trend (%/yr)	P	Annual Index (in 1000s)				
				1970s	1980s	1990s	2000s	% change
Bufflehead	Cavity	-0.367		63.9	80.7	55.8	62.6	-2
Scaup (Lesser and Greater)	Ground	-3.667	*	859.5	604.6	352.1	318.9	-62.9
American Wigeon	Ground	-3.024	*	127	126.7	77.8	58.1	-54.3
Scoter (White-winged and Surf)	Ground	-2.213	*	206.4	162.9	88.5	122.7	-40.5

P is the statistical significance: * indicates P<0.05; n indicates 0.05<P<0.1; no value indicates not significant

Source: data from CWS/USFWS Waterfowl Breeding Population and Habitat Survey

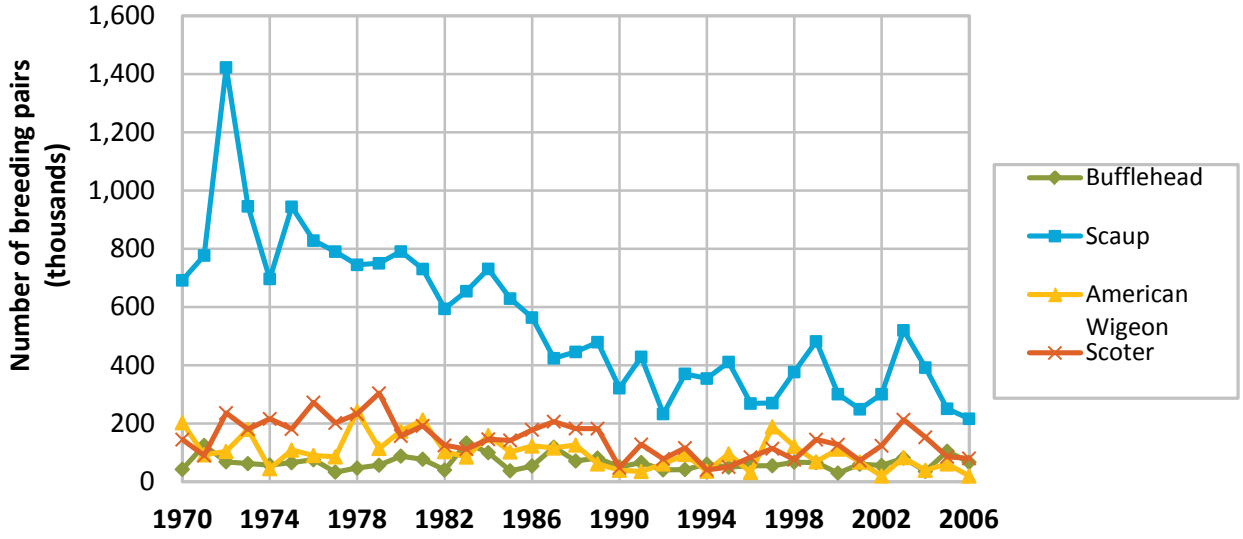

Figure 10. Population trends for breeding Bufflehead, scaup, American Wigeon, and scoter in the western Taiga Shield Ecozone[+], 1970-2006.
Source: data from CWS/USFWS Waterfowl Breeding Population and Habitat Survey

Within the eastern Taiga Shield, population monitoring has been carried out since the early 1990s by the USFWS. These surveys indicate that, although there were considerable year-to-year variations, the long-term trend is stable population levels for all species reported (Table 13 and Figure 11). As noted in the COSEWIC report on Harlequin Ducks (Environment Canada, 2007), hydro and mining projects and forestry activities could be adversely impacting the waterfowl breeding in this area. Hydro and mining project can alter water dynamics over large areas, and forestry activity can increase stream siltation that may affect food availability for the ducks (Crowley and Patten, 1996).

Table 13. Abundance trends for selected breeding waterfowl species in the eastern portion of the Taiga Shield Ecozone[+].

Species	Nesting Habitat	Trend (%/yr)	P	Annual Index (in 1000s)		
				1990s	2000s	% change
Ring-necked Duck	Overwater	2.797		1.2	1.3	2.7
Scaup (Lesser and Greater)	Overwater	1.295		2.2	2.2	-3.1
American Black Duck	Ground	-2.205		7.4	6.6	-10.5
Green-winged Teal	Ground	6.081		2.6	4.5	72.6

P is the statistical significance: no value indicates not significant

Source: data from USFWS Airplane Transect Survey

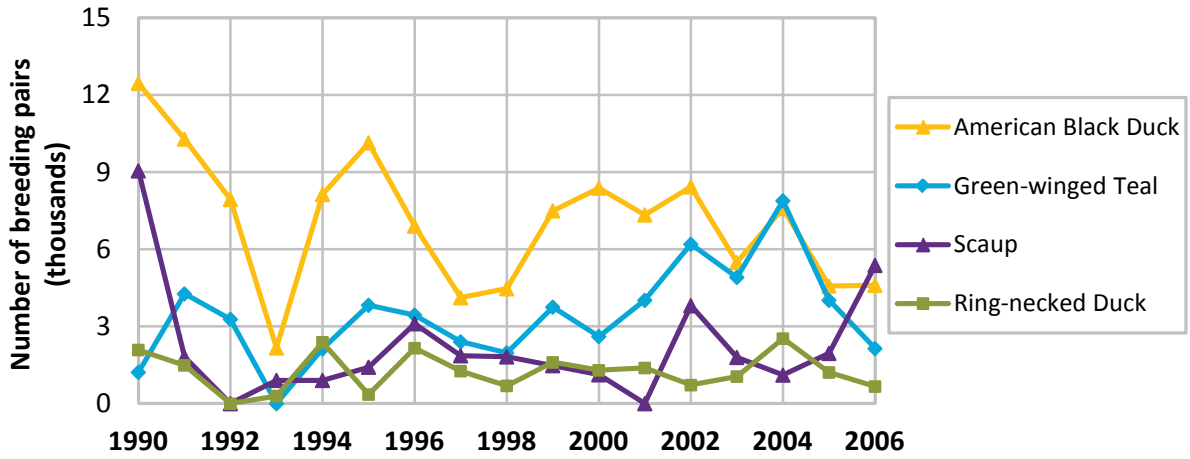

Figure 11. Population trends for breeding American Black Duck, Green-winged Teal, scaup, and Ring-necked Duck in the eastern Taiga Shield Ecozone[+], 1990-2006.
Source: data from USFWS Airplane Transect Survey

Taiga Plains Ecozone[+]

Waterfowl population composition and abundance within the Taiga Plains Ecozone[+] is surveyed by the joint CWS/USFWS Waterfowl Breeding Population and Habitat Survey. Long-tailed Duck, scoters (combined White-winged, Surf, and Black (*M. nigra*), scaup (combined Lesser and Greater), Northern Pintail, Mallard, and American Wigeon show declining population trends (Table 14, Figure 12, and Figure 13). These populations have overlapping breeding areas and most have different wintering areas (Bellrose, 1980) suggesting that reasons for their declines may be linked to this region. Anthropogenic disturbances such as exploration activities for oil and gas have increased recently and may have negative influences on some species (personal observation). Population growth rate for Lesser Scaup may be most sensitive to adult female survival during the breeding and non-breeding seasons and to a lesser extent to nesting success, duckling survival, and juvenile survival (Koons et al., 2006), suggesting that changes to breeding habitat may greatly influence population growth. Similarly, like other seaducks, scoter population growth rates are likely most sensitive to changes in adult survival (Goudie et al., 1994; Robertson and Savard, 2002; Koons et al., 2006).

Table 14. Abundance trends for selected breeding waterfowl species in the Taiga Plains Ecozone[+].

Species	Nesting habitat	Trend (%/yr)	P	Annual Abundance Index (in 1000s)				
				1970s	1980s	1990s	2000s	% change
Bufflehead	Cavity	0.104		96.3	96.2	85.6	97.4	1.2
Long-tailed Duck	Ground	-4.164	*	42.6	30.6	12.5	11.6	-72.8
Scoter (White-winged, Surf, and Black)	Ground	-4.089	*	250.3	233.1	86.4	87.9	-64.9
Scaup (Lesser and Greater)	Ground	-3.273	*	951.8	744.5	427.6	384.3	-59.6
Northern Pintail	Ground	-2.722	*	94.5	69.3	37.6	44.7	-52.7
Mallard	Ground	-2.155	*	232.9	237.2	168.8	131.6	-43.5
American Wigeon	Ground	-2.024	*	194.1	185.5	119.7	121.7	-37.3
Green-winged Teal	Ground	0.665		141.7	249	163.5	201.4	42.2
Canada Goose		0.472		54.7	68.1	63.3	65.4	19.5

P is the statistical significance: * indicates P<0.05; n indicates 0.05<P<0.1; no value indicates not significant

Source: data from CWS/USFWS Waterfowl Breeding Population and Habitat Survey

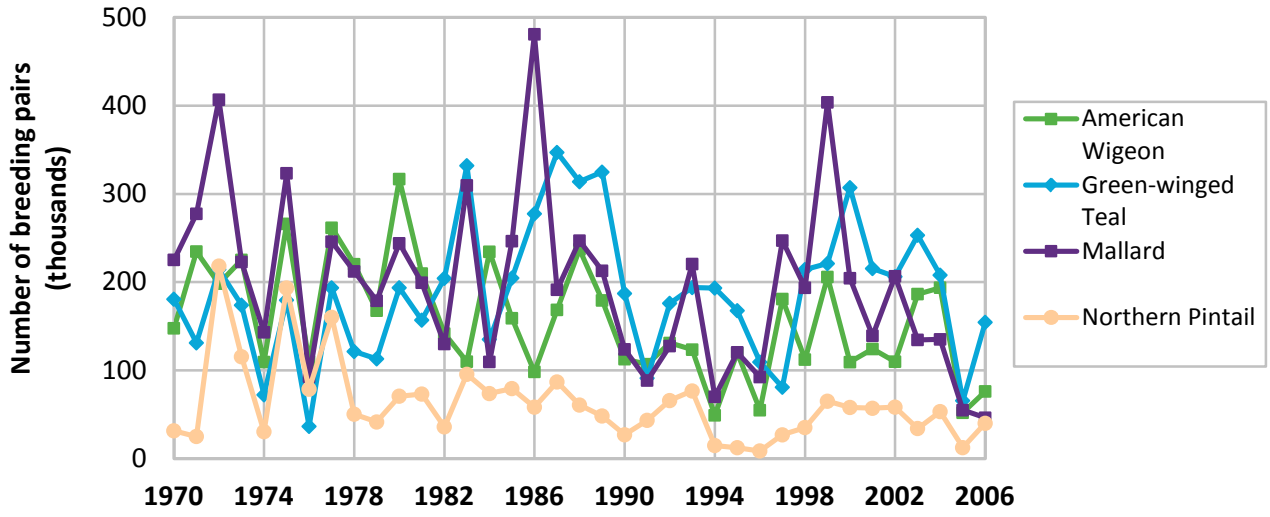

Figure 12. Population trends for breeding American Wigeon, Green-winged Teal, Mallard, and Northern Pintail in the Taiga Plains Ecozone[+], 1970-2006.
Source: data from CWS/USFWS Waterfowl Breeding Population and Habitat Survey

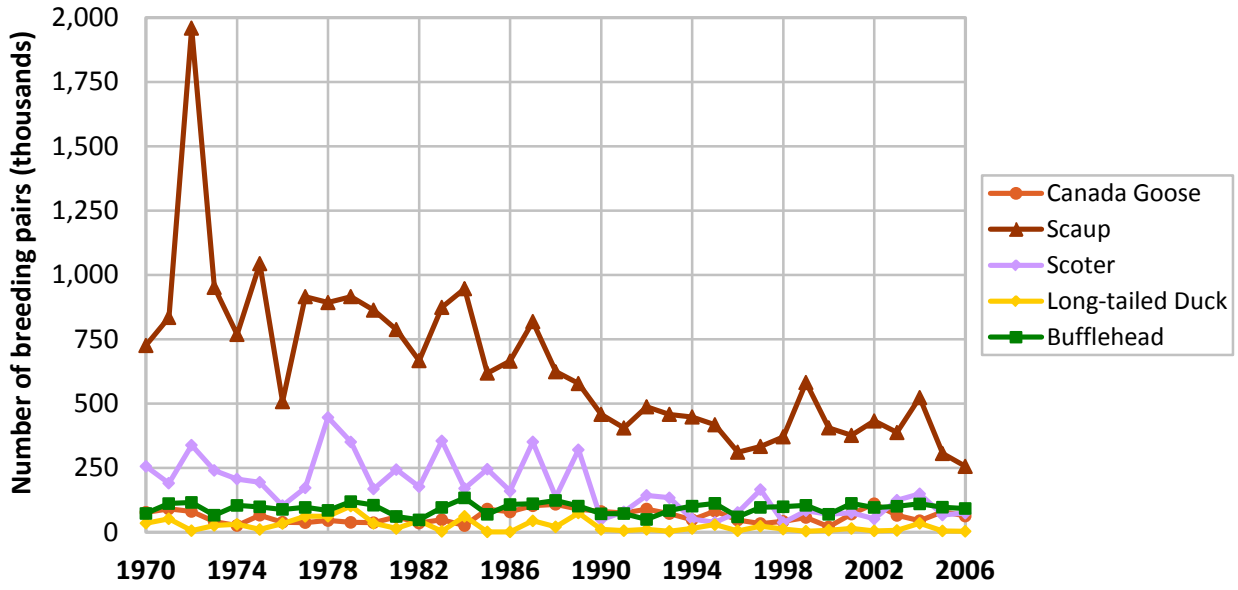

Figure 13. Population trends for breeding Canada Goose, scaup, scoter, Long-tailed Duck, and Bufflehead in the Taiga Plains Ecozone[+], 1970-2006.
Source: data from CWS/USFWS Waterfowl Breeding Population and Habitat Survey

White-winged Scoter pair density and brood occurrence were found to be positively related to amphipod abundance, and broods occurred more frequently on clear wetlands, perhaps due to improved foraging efficiency (Haszard and Clark, 2007). The role of forest fires may be less important as no differences were detected in water chemistry, wetland productivity, or amphipod abundance between wetlands surrounded by recently burned versus unburned forest (Haszard and Clark, 2007). The reasons for the declines of these waterfowl populations are not well understood, as very few waterfowl studies have been conducted in the Taiga Plains. Climate change may play an important role, especially for late-nesting Long-tailed Ducks, scoters, and scaup (see discussions in De Vink et al., 2008; and Drever et al., 2012). As photoperiod is likely the main breeding cue for these species, mismatches in timing may be occurring between their relatively fixed late nesting dates (but see Anteau and Afton, 2009) and invertebrate phenology, which is driven by temperature and has likely changed recently due to climate warming (Corcoran et al., 2009). The mismatch hypothesis between breeding birds and changing food supply, although not yet tested in the taiga regions, has been demonstrated elsewhere (for example Thomas et al., 2001). The mismatch hypothesis however, is one of many that may explain declines in scaup populations (see review in Austin et al., 2000). Causes for the declines observed for Northern Pintail, Mallard, and American Wigeon remain unclear. These species fluctuate greatly between years, and some have declines in other regions as well. Trends for Canada Goose and Green-winged Teal populations have remained unchanged, although the latter has undergone high year-to-year fluctuations, which is typical of this species.

Boreal Plains Ecozone[+]

The distribution, composition, and abundance of waterfowl in the Boreal Plains Ecozone[+] are best covered by the joint CWS/USFWS Waterfowl Breeding Population and Habitat Survey. This ecozone[+] is one of the most important regions for breeding waterfowl in North America (North American Waterfowl Management Plan, 2004). A wide variety of waterfowl are found with a diversity of habitat requirements and migratory strategies. Some winter on Canadian coasts, while the majority winter in the United States and Mexico (Bellrose, 1980). Similar to other regions, the Boreal Plains is experiencing an increase in the population of temperate nesting Canada Geese (310% increase) (Table 15). This is likely due to the species having benefited from the conversion of forest to other land cover types where they can take advantage of food sources (Mowbray et al., 2002).

Table 15. Abundance trends for selected breeding waterfowl species in the Boreal Plains Ecozone[+].

Species	Nesting habitat	Trend (%/yr)	P	Annual Index (in 1000s)				
				1970s	1980s	1990s	2000s	% change
Ring-necked Duck	Overwater	0.775	*	66.1	74.6	95.3	86.6	31
Canvasback	Overwater	1.485	*	31	38.5	48.6	43	38.6
Bufflehead	Cavity	0.241		46.5	37.2	52.9	45.3	-2.7
Goldeneye (Common and Barrow's)	Cavity	1.997	*	42.3	46.7	56.4	76.3	80.2
Scaup (Lesser and Greater)	Ground	-3.522	*	276.4	235.4	174.8	92.2	-66.6
American Wigeon	Ground	-2.891	*	133.1	103.2	90.9	51.6	-61.3
Northern Pintail	Ground	-3.524	*	42.5	32.5	18.7	18	-57.7
Mallard	Ground	-2.161	*	404.6	283.1	286.9	196.9	-51.3
Blue-winged Teal	Ground	-2.603	*	185.7	224.7	123.3	91.6	-50.7
Northern Shoveler	Ground	0.026		44.8	49.9	48.9	43.1	-3.9
Green-winged Teal	Ground	0.125		52.5	53.4	65.3	51.2	-2.5
Canada Goose		4.637	*	12.6	37.5	37.4	51.6	310.6

P is the statistical significance: * indicates P<0.05; n indicates 0.05<P<0.1; no value indicates not significant

Source: data from CWS/USFWS Waterfowl Breeding Population and Habitat Survey

Several waterfowl species have experienced population declines in the Boreal Plains Ecozone[+], including scaup (combined Lesser and Greater), American Wigeon, Northern Pintail, Mallard, and Blue-winged Teal (Table 15 and Figure 14). Broad-scale cumulative impacts from anthropogenic activities (such as, conversion to agriculture, forestry, mining, and oil and gas) have rapidly increased throughout the region and could explain in part the observed trends. For example, rapid deforestation within the Boreal Plains (Hobson et al., 2002) likely has negative implications for many waterfowl similar to those reported for other regions (Stephens et al., 2003; Emery et al., 2005; Koper and Schmiegelow, 2006; Drever et al., 2007). Recent research within the Boreal Plains has found that overall waterfowl abundance was lower in disturbed landscapes, and abundance was similar in burned and logged landscapes (Bidwell et al., 2008). Cavity nesting waterfowl were less abundant in burned landscapes and overwater nesters were

less abundant in logged landscapes (Bidwell et al., 2008). Closer examination of such patterns of boreal waterfowls at the landscape scale suggests that although fire and logging both negatively impact waterfowl populations, these natural and anthropogenic influences seem to be affecting community dynamics differently (Bidwell et al., 2006). In addition to the cumulative impacts from industry in the region, climate change may also have an important role in the declining populations. For example, it is possible that the chronology of breeding birds, which is largely fixed (that is driven by photoperiod) has become out of synchrony with the birds' changing food supply (Corcoran et al., 2009) -- see discussions in De Vink et al. (2008) and Drever et al. (2012). This "mismatch hypothesis", although not yet tested in the boreal region, has been demonstrated elsewhere (Thomas et al., 2001). Despite the factors mentioned above, the processes causing the currently observed waterfowl population trends in the Boreal Plains Ecozone[+] are poorly understood.

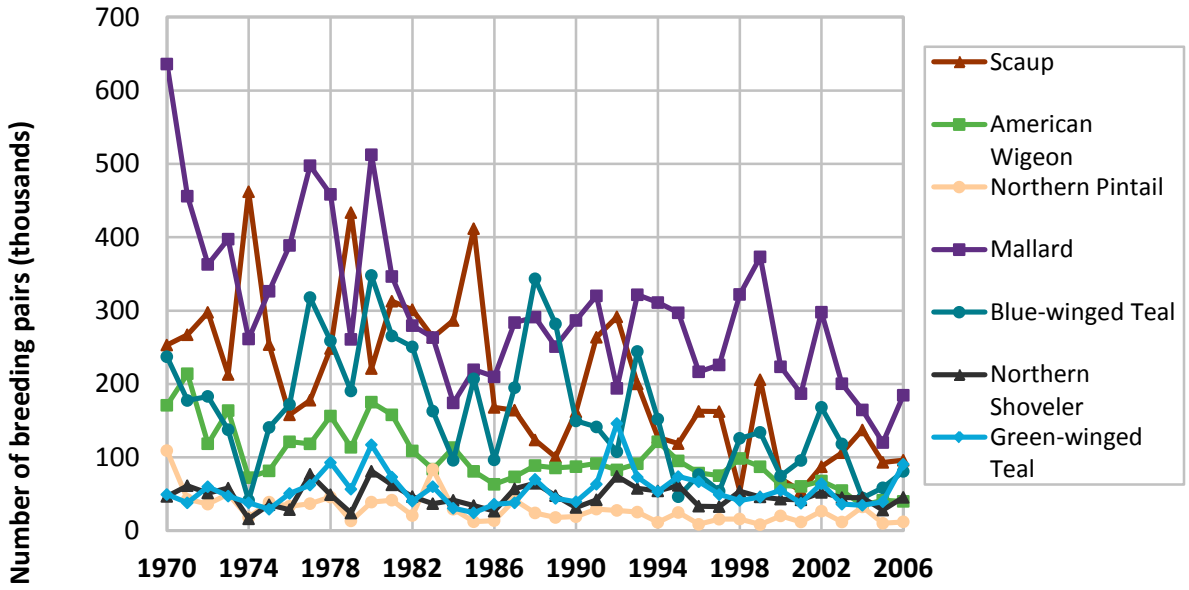

Figure 14. Population trends for scaup, American Wigeon, Northern Pintail, Mallard, Blue-winged Teal, Northern Shoveler, and Green-winged Teal in the Boreal Plains Ecozone[+], 1970-2006.
Source: data from CWS/USFWS Waterfowl Breeding Population and Habitat Survey

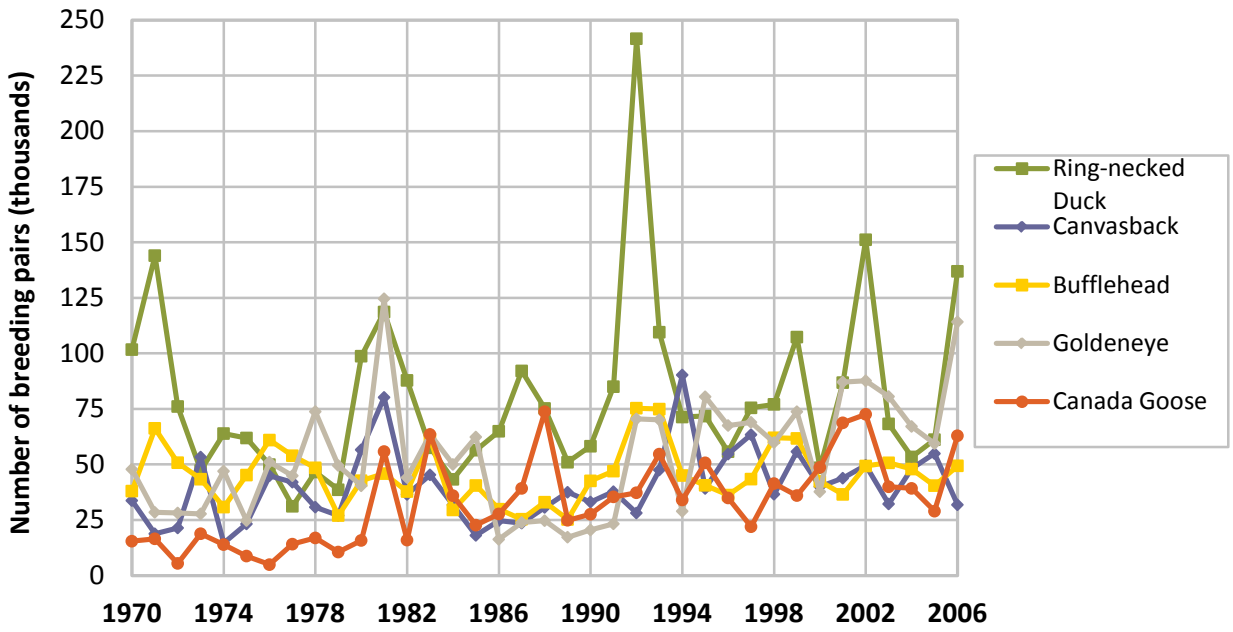

Figure 15. Population trends for breeding Ring-necked Duck, Bufflehead, goldeneye (Common and Barrow's), and Canada Goose in the Boreal Plains Ecozone[+], 1970-2006.
Source: data from CWS/USFWS Waterfowl Breeding Population and Habitat Survey

Prairies Ecozone[+]

The best dataset on waterfowl species distribution, abundance, and community composition for the Prairies Ecozone[+]comes from the joint CWS/USFWS Waterfowl Breeding Population and Habitat Survey. The waterfowl found in the Prairies are diverse, with a variety of different habitat requirements and migratory strategies -- some winter on Canadian coasts while the majority winter in the United States and Mexico (Bellrose, 1980). Although the Prairie Pothole Region covers only 10% of the available breeding habitat for waterfowl in North America, it supports the highest densities of breeding waterfowl and can account for greater than 50% of annual continental duck production (Bellrose, 1980; U.S. Fish and Wildlife Service, 2007). The Prairie Ecozone[+] is also an important area for migrating waterfowl. Many ducks and geese that nest in the Arctic, sub-Arctic, and boreal forest pass through this ecozone[+] during migration, stopping in staging areas.

Some waterfowl species show long-term population increases. For example Canada Goose populations increased by 765% since the 1970s (Table 16). Other species, such as Northern Pintail and American Wigeon, have declined significantly, while others, such as Blue-winged Teal and Canvasback, showed little long-term change (Table 16, Figure 16 and Figure 17).

Table 16. Abundance trends for selected breeding waterfowl species in the Prairies Ecozone[+].

Species	Nesting habitat	Trend (%/yr)	P	Annual Abundance Index (in 1000s)				
				1970s	1980s	1990s	2000s	% change
Canvasback	Overwater	0.3		198	146.7	192.7	206.2	4.2
Redhead	Overwater	0.7	*	279.2	202	285.1	307.5	10.1
Ring-necked Duck	Overwater	0.6	n	47.4	55.2	44.1	57.3	20.8
Ruddy Duck	Overwater	1.6	*	145.5	152.7	196.7	234.8	61.3
Bufflehead	Cavity	2.7	*	59.4	55.5	92.9	112.7	89.9
Northern Pintail	Ground	-4.1	*	2795.3	944.8	816.8	835.5	-70.1
American Wigeon	Ground	-3.6	*	908.6	398.3	356.7	299.6	-67
Green-winged Teal	Ground	-1.5	*	561.3	220.7	346.7	323.8	-42.3
Mallard	Ground	-1.1	*	3180.1	1801	2156.9	2221.2	-30.2
Blue-winged Teal	Ground	-0.1		2024.5	1242.2	1636.8	1835	-9.4
Gadwall	Ground	1.1	*	814.6	585.2	968.4	986.6	21.1
Northern Shoveler	Ground	1.2	*	899.9	654.7	1022.9	1254	39.3
Canada Goose	Ground	7.9	*	47.7	107.9	238.6	412.4	765.4

P is the statistical significance: * indicates P<0.05; n indicates 0.05<P<0.1; no value indicates not significant

Source: data from CWS/USFWS Waterfowl Breeding Population and Habitat Survey

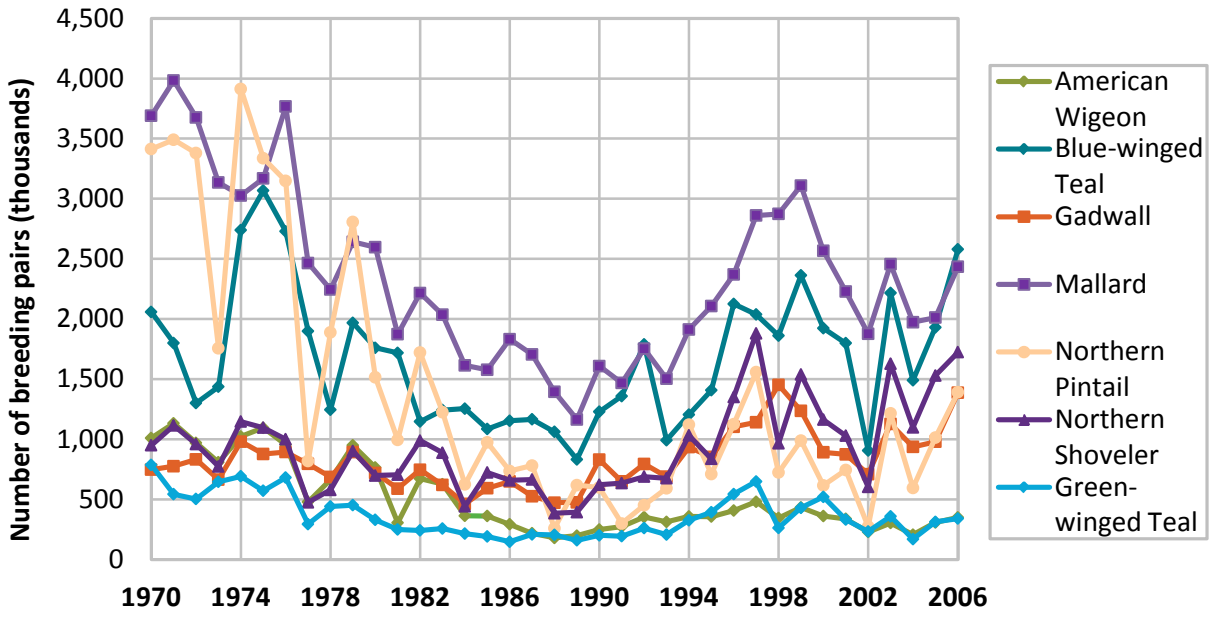

Figure 16. Population trends of selected ground nesting ducks (American Wigeon, Blue-winged Teal, Gadwall, Mallard, Northern Pintail, and Northern Shoveler) and Green-winged Teal in the Prairies Ecozone[+], 1970-2006.

Source: data from CWS/USFWS Waterfowl Breeding Population and Habitat Survey

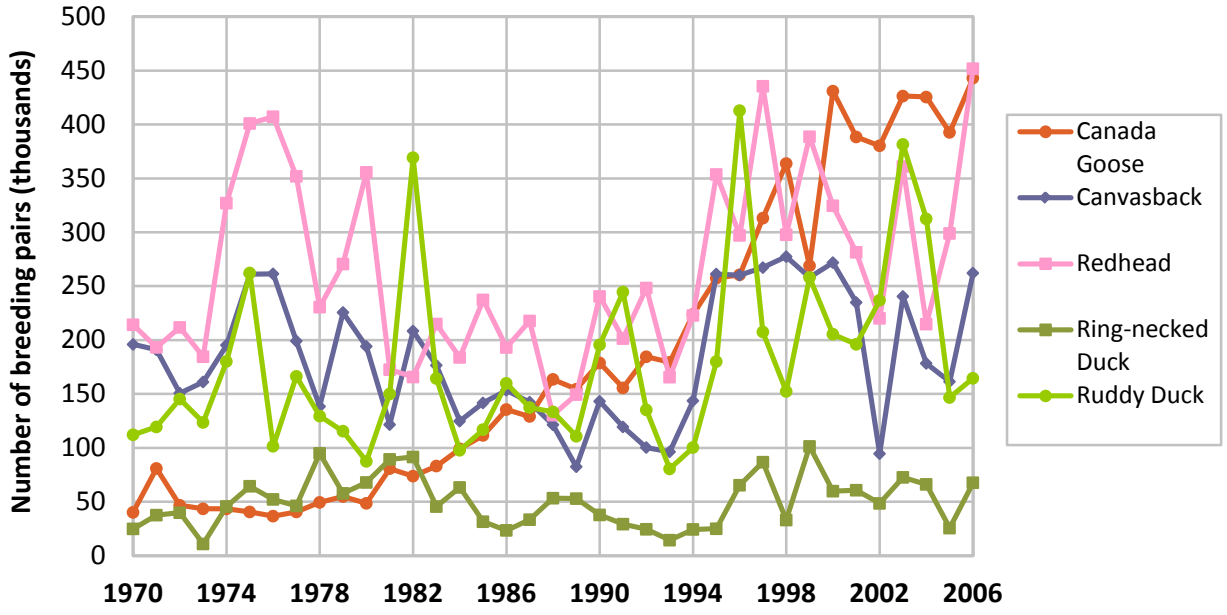

Figure 17. Population trends for breeding Canada Goose and selected over-water nesting ducks (Canvasback, Redhead, Ring-necked Duck, and Ruddy Duck) in the Prairies Ecozone[+], 1970-2006. Source: data from CWS/USFWS Waterfowl Breeding Population and Habitat Survey

Canada Geese appear to easily adapt to a variety of habitats including farmland and urban areas, likely benefitting from the conversion of deciduous forest and natural prairie to these land cover types by taking advantage of cereal grain, planted forage, and turf grass food sources (Mowbray et al., 2002). Similarly, management practices, such as re-establishment of local populations by relocating moulting adults and juveniles from other locations, has benefitted Canada Goose populations (Nieman et al., 2000; Mowbray et al., 2002). The population increase observed in the Prairies is consistent throughout the breeding range of the temperate breeding goose (Canadian Wildlife Service Waterfowl Committee, 2008).

Intensification of agricultural practices, including decreased use of summerfallow and increased conversion of marginal land to cropland, over the last 40 years has likely had negative impacts on breeding waterfowl on the Prairies through habitat loss and changes in predation patterns. For example, nest success for Mallard, Northern Pintail, Northern Shoveler, Blue-winged Teal, and Gadwall in the Prairie Pothole Region is negatively associated with the proportion of cropland (Drever et al., 2007). Landscape-level fragmentation has also increased (Stephens et al., 2003). Some avian species in southern Alberta were found to respond to habitat characteristics at spatial scales similar to their home range and territory size (with the exception of Northern Pintail), suggesting that fragmentation effects may vary with home range or territory size of individual species (Koper and Schmiegelow, 2006). Northern Pintail prefer to nest in sparse cover away from water, often in standing stubble, mulched stubble, or fallow fields early in the nesting season often prior to cultivation and planting (Austin and Miller, 1995). Since the 1970s, summerfallow has been increasingly converted to annual cropping, with fallow land being reduced by nearly 4 million hectares from 1971 to 1995 (Statistics Canada 1995 cited in Carlyle,

1997), and reduced from comprising 17.7% of agricultural land in 1986 to 7.3% in 2006 in the Prairie Ecozone+ (Javorek and Grant, 2011). This reduction in fallow land has been linked to the declining prairie population of Northern Pintail (Austin and Miller, 1995; Podruzny et al., 2002). Waterfowl nest success early in the breeding season was found to be lower in unmanaged nesting cover types (for example, cropland, hay land, and pasture) compared to managed cover (for example, delayed grazing, planted cover, idled pasture, and idled parkland) (Emery et al., 2005). Hoekman et al. (2002) suggested that, when comparing vital rates at various stages of the annual cycle, predation processes on the breeding grounds, inferred by nest success and female survival during the breeding season, is the primary proximate factor limiting population growth of midcontinent Mallards.

Climatic conditions also have a large impact on waterfowl populations in the Prairies. The protracted wide scale prairie drought in the 1980s had negative effects on waterfowl populations, although many species have since steadily increased (Table 16). Wetland abundance and distribution affects several demographic vital rates of prairie breeding ducks, including nesting intensity, brood survival, and adult survival (Krapu et al., 1983; Cowardin et al., 1985; Krapu et al., 2000; Devries et al., 2003), in addition to settlement and return rates (Johnson and Grier, 1988; Dufor and Clark, 2002). Northern Pintail, Blue-winged Teal, Mallard, and Northern Shoveler breeding densities fluctuated with numbers of prairie ponds, suggesting that these species fly over the Prairies in drought years and settle in more northern ecozones+ (Johnson and Grier, 1988). These species, along with Green-winged Teal, are dabbling ducks that are typically associated with shallow temporary and seasonal wetlands. Consequently, some of these species may be more sensitive to fluctuating water conditions (including wetland densities) and wetland destruction than other species, such as Gadwall and diving ducks (such as Canvasback and Ruddy Duck), which are associated with semi-permanent and permanent wetlands. As such, duck species that use small wetlands prone to agricultural modification or destruction and climate fluctuations are generally the species showing population declines (Table 16).

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