COSEWIC
Assessment and Status Report

on the

Eastern Wolf
Canis sp. cf. *lycaon*

in Canada

THREATENED
2015

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

COSEWIC. 2015. COSEWIC assessment and status report on the Eastern Wolf *Canis* sp. cf. *lycaon* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xii + 67 pp. (www.registrelep-sararegistry.gc.ca/default_e.cfm).

Previous report(s):

COSEWIC 2001. COSEWIC assessment and update status report on the eastern wolf *Canis lupus lycaon* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 19 pp.

Samson, C. 2001. Update COSEWIC status report on the eastern wolf *Canis lupus lycaon* in Canada, *in* COSEWIC assessment and update status report on the eastern wolf *Canis lupus lycaon* in Canada.

Van Zyll de Jong, C.G., and L.N. Carbyn. 1999. COSEWIC status report on the Grey Wolf *Canis lupus* in Canada. Committee on the Status of Endangered Wildlife in Canada. 61 pp.

Production note:
COSEWIC would like to acknowledge Linda Rutledge for writing the status report on the Eastern Wolf (*Canis* sp. cf. *lycaon*), prepared under contract with Environment Canada. Modifications to the status report after acceptance of the provisional report were overseen by Graham Forbes, Co-chair of the COSEWIC Terrestrial Mammals Specialist Subcommittee (TM SSC), based on comments from jurisdictions, the TM SSC, COSEWIC members, and external experts.

For additional copies contact:

COSEWIC Secretariat
c/o Canadian Wildlife Service
Environment Canada
Ottawa, ON
K1A 0H3

Tel.: 819-938-4125
Fax: 819-938-3984
E-mail: COSEWIC/COSEPAC@ec.gc.ca
http://www.cosewic.gc.ca

Également disponible en français sous le titre Évaluation et Rapport de situation du COSEPAC sur le Loup de l'Est (*Canis* sp. cf. *lycaon*) au Canada.

Cover illustration/photo:
Eastern Wolf — Photograph of Eastern Wolf from Algonquin Provincial Park. © Michael Runtz, used with permission.

Catalogue No. CW69-14/719-2015E-PDF
ISBN 978-0-660-02611-4

COSEWIC
Assessment Summary

Assessment Summary – May 2015

Common name
Eastern Wolf

Scientific name
Canis sp. cf. *lycaon*

Status
Threatened

Reason for designation
This species is an intermediate-sized canid with a generally reddish-brown/tawny coat. It has a small population size (likely < 1000 individuals) and a restricted range, limited to south-central Ontario and south-central Quebec. Most records come from scattered protected areas, where mortality and rates of hybridization with Eastern Coyotes occurs less frequently than elsewhere in its range. Population expansion is unlikely, owing to competition with Eastern Coyote and increased mortality outside protected areas.

Occurrence
Ontario, Quebec

Status history
In 1999, the Eastern Grey Wolf (*Canis lupus lycaon*) was considered a subspecies of the Grey Wolf and was placed in the Data Deficient category. Status was re-examined (as Eastern Wolf, *Canis lupus lycaon*) and designated Special Concern in May 2001. New genetic analyses indicate that the Eastern Wolf is not a subspecies of Grey Wolf. In May 2015, a new wildlife species, Eastern Wolf (*Canis* sp. cf. *lycaon*) was designated Threatened.

COSEWIC
Executive Summary

Eastern Wolf
Canis sp. cf. *lycaon*

Wildlife Species Description and Significance

The Eastern Wolf (putatively *Canis lycaon*, formerly *Canis lupus lycaon*) is an intermediate-sized canid weighing an average 24 kg for females and 29 kg for males. Pelage often is described as reddish-brown/tawny, but is highly variable. The Eastern Wolf is best defined by a combination of genetic distinctiveness, morphological characters, and an ecological role associated with a feeding preference for smaller prey than fed on by Gray Wolf (*C. lupus*). The Eastern Wolf population has a degree of hybridization with Coyote (*C. latrans*), and individuals are defined based on having a high level of genetic 'purity,' that is, distinctiveness from both Gray Wolf and Coyote as determined by molecular genetic analysis. It is important to note that the Eastern Wolf discussed in this report is not the same Eastern Wolf discussed in the Great Lakes region because those *Canis* are considered in this report as Great Lakes-Boreal Wolves, a hybrid between the Eastern Wolf and Gray Wolf. Although evidence is strong that the Eastern Wolf is a valid species, the taxonomy of Eastern Wolf is under debate; in this report the Eastern Wolf is considered to be *Canis sp. c.f. lycaon*, a wildlife species as defined under SARA that is worthy of conservation because of its distinctiveness, persistence, and significance as a large carnivore, and likely part of the last remnant population of the large *Canis* from eastern North America. Aboriginal traditional knowledge also supports the existence of a medium-sized *Canis* in the region.

Distribution

The current distribution of Eastern Wolves is thought to be restricted to the mixed coniferous-deciduous forests of central Ontario and southwestern Québec, namely the Great Lakes-St. Lawrence Forest Region. Eastern Wolves were extirpated from most of their original range in North America due to eradication of large *Canis* over much of the past 400 years. Genetic analyses suggest that the current distribution of Eastern Wolves mainly is in central Ontario and southern Québec (north of the St. Lawrence River), with concentrations in core areas, all of which are protected areas.

Habitat

Eastern Wolves typically occur in deciduous and mixed forest landscapes with low human density, south of the Boreal Forest Region. Sandy soils are often preferred for den sites. Both den and rendezvous sites tend to be located in conifer/hardwood-dominated landscapes near a permanent water source. Territory size is often near 200 km^2.

Biology

Eastern Wolves live in family-based packs composed of a breeding pair and offspring from the current and previous years. Females give birth to an average of five pups in late April - early May and they remain at the den site for 6 - 8 weeks. Dispersing juveniles leave the pack after 37 weeks. Eastern Wolves are primarily predators of White-tailed Deer (*Odocoileus virginianus*). Predator-prey and diet analyses indicate that Eastern Wolves can be effective predators of Moose (*Alces americanus*), although efficiency varies by pack, season, and year. Beaver (*Castor canadensis*) also constitutes a substantial portion of Eastern Wolf diet.

Population Sizes and Trends

There have been 170 - 195 Eastern Wolf (all ages) identified in the last 10-15 years. The population size is unknown but likely less than 1000 mature individuals. The estimated minimum population size is 236 mature individuals, mainly located within protected areas. A best-possible-scenario maximum estimate of 1203 mature individuals within the extent of occurrence is based on there being an equally high density of Eastern Wolf outside protected areas. Most records though occur in protected areas and the population size of mature Eastern Wolf likely is closer to 236 individuals. There is no population trend information except for Algonquin Park, the site with the most Eastern Wolf records to date, which appears to be stable.

Threats and Limiting Factors

The main threat and limiting factor for Eastern Wolves outside the protected areas likely is human-caused mortality from hunting and trapping, which is facilitated by road networks. Based on research in Algonquin Park, excessive mortality likely limits dispersal, and alters pack breeding dynamics, leading to another main threat, gene introgression (hybridization) with Eastern Coyotes due to the lack of conspecific mates. Habitat loss and fragmentation associated with road networks and urbanization is expected to continue outside protected areas and likely will deter population expansion. Negative public attitudes towards wolves, and established packs of Eastern Coyote, may limit population expansion.

Protection, Status, and Ranks

The Eastern Wolf is listed as Special Concern under the federal *Species at Risk Act* (SARA) and Ontario's *Endangered Species Act, 2007*. Both listings are as a subspecies of Gray Wolf (*Canis lupus lycaon*). No wolf species is listed under the *Lois sur les espèces menacées ou vulnérables* [*Act respecting Threatened or Vulnerable Species in Québec*]. Hunting and trapping of wolves is permitted in wildlife reserves, but not in national (federal or provincial) parks. In Ontario, wolves are protected from regulated hunting and trapping in Algonquin Park, in the townships surrounding Algonquin Park, and in all provincial Crown Game Preserves. Eastern Wolves are protected from hunting, but not from trapping, in French River Park. Wolves are protected from harvest in national parks. Aboriginal communities retain constitutional rights to harvest Wolves for sustenance and ceremonial purposes, including in protected areas. A small game licence is required to hunt Wolves in Ontario (limit of 2 per year) and Québec (no bag limit). NatureServe ranks *Canis lupus lycaon as* N4 (apparently secure). At the provincial scale, Eastern Wolf is ranked as S4 ('apparently secure') in Ontario, and is not ranked in Québec.

TECHNICAL SUMMARY

Genus species: *Canis sp. c.f. lycaon*

Common Name: Eastern Wolf Loup de l'Est

Range of occurrence in Canada: Ontario, Québec

Demographic Information
See Population Sizes and Trends, Fluctuations and Trends, and Abundance Sections

Generation time Age of first breeding is > 2 years and adult lifespan highly variable depending on mortality rates.	3.5 yrs
Is there an inferred continuing decline in number of mature individuals? The subpopulation in Algonquin Park appears stable but subpopulations elsewhere are not well surveyed; subpopulations in the larger area are small and relatively isolated and likely experience threats such as habitat alteration, road building, hunting/trapping, hybridization with Eastern Coyotes that decrease the population.	Possibly
Estimated percent of continuing decline in total number of mature individuals within 2 generations (7 years). (see above)	Unknown
Suspected percent reduction in total number of mature individuals over the last 3 generations (10.5 yrs). Unknown for most of range but in Algonquin Park area, the number of mature animals decreased 20% from 2002 – 2007 due to disease, but have since increased.	Unknown
Suspected percent reduction in total number of mature individuals over the next 3 generations (10.5 yrs). (see above)	Unknown
Observed/suspected percent reduction in total number of mature individuals over any 3 generation period (10.5 yrs), over a time period including both the past (observed) and the future (suspected). No evidence of recent decline. Historical decrease of approximately 50% of its Canadian range. Human-caused mortality between 1964 - 1971 (< 16% decline), and 1991 - 1999 in the Algonquin subpopulation (< 12% decline) (see Fluctuations and Trends).	Unknown
Are the causes of the decline clearly reversible and understood and ceased? The cause of the historical decline was targeted eradication, which has ceased. Harvest outside protected zones has not ceased and continues to be a significant threat. Harvest could be a cause of potential future decline via gene introgression by Eastern Coyotes.	No
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information
See Distribution Section

Estimated extent of occurrence Extent of occurrence (EOO) based on all records	126,573 km²
Index of area of occupancy (IAO) The area of occupancy, based on size of sites containing Eastern Wolf records, is 29,472 km^2.	>10,000 km²
Is the total population severely fragmented? The total population is fragmented by regions where there is no protection, high road networks, higher human density, and increased risk of hybridization with Eastern Coyotes.	Yes
Number of locations* Population exists mainly in 11 sites (plus numerous townships around Algonquin Park), and animals exist in numerous packs. If causes of mortality are independent among packs, then locations would be > 20.	Unknown, likely >20
Is there an inferred continuing decline in extent of occurrence? *Canis* mortality outside protected regions likely limits expansion of the range but the EOO is based on recent genetic tests and declines have not been noted over this short time period.	Unknown
Is there an inferred continuing decline in index of area of occupancy? (see above)	Unknown
Is there an inferred continuing decline in number of populations? (see above)	Unknown
Is there an inferred continuing decline in number of locations? Wolf harvest outside protected regions may impact the locations.	Unknown
Is there an inferred continuing decline in area, extent and/or quality of habitat? Hunting and trapping limit ability to establish relatively non-hybridized packs in other locations. Land conversion and road building in potential dispersal areas decreases habitat quality.	Yes
Are there extreme fluctuations in number of populations?	Unknown, but unlikely
Are there extreme fluctuations in number of locations?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

* See Definitions and Abbreviations on COSEWIC website and IUCN 2010 (not in information sources) for more information on this term.

Number of Mature Individuals (in each population)
See Population Sizes and Trends section

Population	**N Mature Individuals**
Ontario-Québec Estimated minimum number of mature individuals is 236, based on extrapolating results from several study areas to size of protected areas where Eastern Wolf have been recorded. A maximum estimate of 1203 mature individuals may occur within the extent of occurrence but only if it is assumed that areas outside protected areas have the same density of Eastern Wolf, which is very unlikely because few animals have been recorded outside protected areas. The population of mature individuals likely is closer to 236.	
Total	Unknown, but very likely < 1000

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years]. Several analyses were done > 10 years ago but only for the Algonquin Park area; methods varied, genetic issues were not included, and overall, their application is limited. One population viability analysis concluded cause for concern, while another concluded that the population was secure.	Not available

Threats (actual or imminent, to populations or habitats)
See Threats and Limiting Factors section

Hunting and Trapping, Gene introgression from Eastern Coyote, Road Networks facilitate mortality levels. Access to most of range limited by competition from established populations of Eastern Coyote.

Rescue Effect (immigration from outside Canada)
See Rescue Effect Section

Status of outside population(s)? No populations outside Canada are known. The Red Wolf is an unviable candidate for a translocation rescue effect in Canada because its genome has been impacted by founder effects and extensive hybridization. Natural colonization by Red Wolves is unlikely due to the high human density throughout the ≈1000 km geographic separation of the two populations.	
Is immigration known or possible?	No
Would immigrants be adapted to survive in Canada? There is no immigrant source.	N/A
Is there sufficient habitat for immigrants in Canada?	N/A
Is rescue from outside populations likely?	No

COSEWIC Status History

In 1999, the Eastern Grey Wolf (*Canis lupus lycaon*) was considered a subspecies of the Grey Wolf and was placed in the Data Deficient category. Status was re-examined (as Eastern Wolf, *Canis lupus lycaon*) and designated Special Concern in May 2001. New genetic analyses indicate that the Eastern Wolf is not a subspecies of Grey Wolf. In May 2015, a new wildlife species, Eastern Wolf (*Canis* sp. cf. *lycaon*) was designated Threatened.

Status and Reasons for Designation

Status: Threatened	**Alpha-numeric code:** D1
Reasons for designation: This species is an intermediate-sized canid with a generally reddish-brown/tawny coat. It has a small population size (likely < 1000 individuals) and a restricted range, limited to south-central Ontario and south-central Quebec. Most records come from scattered protected areas, where mortality and rates of hybridization with Eastern Coyotes occur less frequently than elsewhere in its range. Population expansion is unlikely, owing to competition with Eastern Coyote and increased mortality outside protected areas.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable. No evidence of a population decline.
Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable. EOO (126,573 km²) and IAO (29,472 km²) exceed thresholds.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable. No evidence of a population decline.
Criterion D (Very Small or Restricted Total Population): Meets D1 Threatened; population of mature individuals is < 1000.
Criterion E (Quantitative Analysis): Not applicable. Adequate population viability analyses have not been conducted on entire population.

PREFACE

In 1999, the Eastern Wolf was labelled ‘Eastern Grey Wolf’ (*Canis lupus lycaon*), a subspecies of Grey Wolf within the COSEWIC Grey Wolf report (van Zyll de Jong and Carbyn 1999), and assessed as Data Deficient. In 2001, the Eastern Wolf was listed as Special Concern (Samson 2001). Debate exists about the taxonomic status of the Eastern Wolf but there is now consensus that the Eastern Wolf is not a subspecies of Grey Wolf (Kyle *et al.* 2006; vonHoldt *et al.* 2011; Rutledge *et al.* 2012). In this COSEWIC report the Eastern Wolf is considered to be *Canis sp. c.f. lycaon* and individuals are identified based on a high level of ‘purity’ (*i.e*., Q≥80 of a genetic cluster unique to *C. lupus* and C. *lycaon*). Individuals with Q<80 are considered too hybridized to warrant being Eastern Wolf and are not included in estimates of abundance and distribution.

Throughout this report, the term “Eastern Wolf” will be used to identify the intermediate-sized canid that occurs in central Ontario and southwestern Québec. As per the 3-species hypothesis, “Eastern Coyote” will be used for the smaller Coyote – Eastern Wolf *Canis* hybrid (also known as Tweed Wolf, Brush Wolf, or Coywolf) that occurs from Ontario to Newfoundland, whereas “Great Lakes-Boreal Wolf” will be used for the putative Grey Wolf – Eastern Wolf *Canis* hybrid that occurs in more northern boreal forest landscapes of Manitoba, Ontario, and Québec. The term “Grey Wolf” will be used to refer to the larger non-hybridized wolf found in northwestern regions of Canada and “Coyote” (*C. latrans*) will be used to refer to the smaller non-hybridized Coyote from western North America. Only the status of Eastern Wolf is addressed in this COSEWIC report.

As part of COSEWIC status assessments, Aboriginal traditional knowledge (ATK) reports are prepared by the Aboriginal Traditional Knowledge Subcommittee (ATK SC). These initial reports compile and summarize ATK relevant to status assessment when ATK information is available and readily accessible. A Gathering Report may be undertaken if there are significant knowledge gaps, or if major contradictions exist between ATK and other forms of knowledge. The initial process used by the ATK SC did not identify ATK specific to the Eastern Wolf in Canada, but information was provided to the ATK SC after the 2-month review period, and that information is included in the report.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2015)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

Environment Canada / Environnement Canada
Canadian Wildlife Service / Service canadien de la faune
Canada

The Canadian Wildlife Service, Environment Canada, provides full administrative and financial support to the COSEWIC Secretariat.

COSEWIC Status Report

on the

Eastern Wolf
Canis sp. cf. *lycaon*

in Canada

2015

TABLE OF CONTENTS

List of Figures

List of Tables

List of Appendices

WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Common Name: Eastern Wolf (English); Loup de l'Est (French)

Other Names: Eastern Canadian Wolf, Eastern Timber Wolf, Algonquin-Type Gray Wolf, Algonquin Wolf

Class: Mammalia

Order: Carnivora

Family: Canidae

Genus: *Canis*

Species: putatively *Canis lycaon* Schreber 1775; (Wilson *et al.* 2000) [formerly *Canis lupus lycaon* – Algonquin type (Goldman 1937)] but reported here as Eastern Wolf (*Canis* sp. c.f. *lycaon*)

COSEWIC Eligibility

The taxonomy of the Eastern Wolf is under debate and this report begins with a discussion of its eligibility for assessment by COSEWIC. COSEWIC criteria for species eligibility are based on: taxonomic validity (defined by peer-reviewed publications and communication with specialists); being native to Canada (naturally occurring or present for > 50 years); and occurring regularly in Canada (COSEWIC 2014).

Taxonomic Validity

At present, COSEWIC lists the Eastern Wolf as a subspecies of Gray Wolf (*Canis lupus lycaon*) (Samson 2001). However, based on genetic analyses in the last 10 years, there is now widespread agreement that the Eastern Wolf is not a subspecies of the Gray Wolf (see Appendix A). The taxonomic validity of Eastern Wolf is outlined below, and discussed in detail in Appendix A.

The large *Canis* east of the Great Lakes region has consistently been recognized as unique, and has been classified as a species, or subspecies for over 200 years. The type specimen for Eastern Wolf was collected (likely) near Québec City, Québec in 1761, and named *Canis lycaon* by Schreber in 1775 (Miller 1912; Manning and Sturtevant 1966). In the first major revision of *Canis*, Pocock (1935) used differences in morphology to retain the Eastern Wolf (re-labelled as Eastern Canadian Wolf) as a full species, and defined all remaining *Canis* in central and north North America as subspecies of Gray Wolf. Goldman (1937) labelled the Eastern Wolf as *Canis lupus lycaon* – Algonquin type. The inclusion of *C. lycaon* as a subspecies of *C. lupus* was due to a similarity in skull measurements to other *Canis*. Since then, the Eastern Wolf has been consistently recognized in all morphometric-based analyses as the smallest sized of all *C. lupus* subspecies (Young and Goldman 1944; Nowak 1995).

Aboriginal traditional knowledge from the Mohawk First Nation of Akwesasne notes that more than one type of Canid was recognized in the region before European contact, based on differences in body size, temperament, and size of prey consumed (Lickers pers. comm. 2015). The 'little wolf' was considered to be 'nice' (as compared to the more feared [Gray] Wolf) and are known to prey on White-tailed Deer. A smaller canid (Coyote) arrived later in the region (Lickers pers. comm. 2015).

Kyle *et al.* (2006), Chambers *et al.* (2012), and Mech *et al*. (2014) provide extensive reviews on the taxonomic history of the Eastern Wolf, and Mech (2011) documents the non-genetic evidence for the existence of the Eastern Wolf. Other reviews are found in Cronin and Mech (2009), Schwartz and Vucetich (2009), Mech (2010a), Benson *et al*. (2012), and Rutledge *et al.* (2012). Much of the debate on the taxonomy of *Canis* is associated with the arrival of Coyote (*Canis latrans*) into eastern North America. In a continental-scale invasion, Coyotes from the Prairie region of North America expanded northward and eastward; the first record in southeastern Ontario was in 1919 (Nowak 1979). These small *Canis* (e.g., adult male averages of 13 - 14 kg in different parts of the central Prairies [Parker 1995]) bred with a larger *Canis* in the Great Lakes region and produced an intermediate-sized animal (e.g., adult male averages of 14.6 - 21 kg in different parts of northeastern North America [Parker 1995; Villemure and Jolicoeur 2004]). The new animal, named the Eastern Coyote, then established itself across eastern Canada, reaching Québec in 1944, Nova Scotia in the 1970s, and Newfoundland in 1985 (Parker 1995; Naughton 2012).

There is widespread agreement that the Eastern Coyote is a hybrid (Wilson *et al*. 2009; vonHoldt *et al*. 2011). The debate is whether the large *Canis* that bred with Coyote was the Gray Wolf, or the Eastern Wolf. In the 2-species hypothesis, the large *Canis* was a Gray Wolf, which resulted an array of hybrid *Canis* (*i.e.*, Eastern Wolf, Red Wolf (*C. rufus,* a listed species in the United States), Great-Lakes Boreal Wolf, and Eastern Coyote) (Lehman *et al*. 1991; Kays *et al.* 2010; vonHoldt *et al*. 2011). The Eastern Coyote, Eastern Wolf, and Red Wolf are intermediate in size to the Gray Wolf and Coyote; this intermediate size fits the expected outcome of a hybridization event and is part of the basis for the argument that the Eastern Wolf is not a species.

In the other hypothesis (the 3-species model), the large *Canis* that bred with the 'western' Coyote was a separate species named Eastern Wolf (or Red Wolf) that existed mainly in eastern North America. The third species, Gray Wolf, immigrated from Eurasia 300,000 years ago (Wilson *et al*. 2003). In this hypothesis, the Eastern Wolf is a true species and the Eastern Coyote is a hybrid that resulted from mating between Coyote and Eastern Wolf, not between Coyote and Gray Wolf (Rutledge *et al.* 2012; Rutledge *et al.* in revision). Another large *Canis*, the Great Lakes-Boreal Wolf (see **Search Effort**) is a hybrid that resulted from Eastern Wolf breeding with Gray Wolf (e.g. Wheeldon and White 2009; Wheeldon *et al.* 2010; Fain *et al.* 2010; Rutledge *et al.* 2012, in review).

There have been publications (see Appendix A) where the Great Lakes-Boreal Wolf has been called Eastern Wolf (*Canis lycaon*) but, in this report, the Eastern Wolf refers to what is believed to be the most 'pure' and remnant population of the progenitor of the Great Lakes-Boreal Wolf and Eastern Coyote hybrids.

The evidence that Eastern Wolf should be considered a separate species is strong (Appendix A), but COSEWIC recognizes that the debate continues (*i.e*., NCEAS 2014) and the taxonomic issue is not entirely resolved at present. As well, the extant population of the putative Eastern Wolf includes some level of Coyote genes, and the basis for identifying individuals is derived from applying a probability of assigning an individual to a genetically similar, and thus identifiable, 'cluster' (Appendix B).

Notwithstanding the taxonomic debate, there is consensus that a unique *Canis* has been recognized to exist in the region since the mid-1700s and currently exists in parts of Ontario and Québec (Appendix A). The animal exploits a different ecological niche than *Canis lupus*-like canids and *C. latrans*-like canids (see **Interspecific Interaction**). It is largely found in minimally human-impacted mixed-woods plains region of Canada. Its contemporary distribution is influenced by genetic introgression from hybridization with Eastern Coyote in more anthropogenically altered regions in the south of Ontario and Québec, and hybridization with *C. lupus* in more boreal-dominated regions containing more Moose (Appendix A). Hence, there is a unique canid that exploits an ecological niche in, or proximate to, a few small protected regions of Ontario and Québec; protecting the largest canid within this narrowing/threatened ecological niche is a conservation concern.

A wildlife species is defined in the *Species at Risk Act* (SARA) and COSEWIC (2014) as a species, subspecies, variety or geographically or genetically distinct population that is native to Canada and wild by nature. The Eastern Wolf is not a subspecies of Gray Wolf (see Taxonomic Validity) and therefore could not be a Designatable Unit of Gray Wolf. In summary, this report considers the Eastern Wolf as a unique, persistent, and evolutionarily significant wildlife species in Canada. The remaining Eastern Wolves are naturally occurring residents in Canada that have been present for > 50 years. A plausible mechanism exists for the maintenance of the Eastern Wolf in regional sympatry with the Eastern Coyote (see Appendix A). The proposed name for this report is Eastern Wolf (*Canis* sp. c.f. *lycaon*) (Appendix E4 in COSEWIC 2014).

Morphological Description

The high plasticity in morphological features, especially in body size ranges (Rutledge *et al.* 2010c), makes the Eastern Wolf difficult to distinguish from Great Lakes-Boreal Wolves and Eastern Coyotes without assignment tests based on genetic markers. However, Eastern Wolves (Figure 1) have been differentiated from both Great Lakes-Boreal Wolves and Eastern Coyotes in skull morphology, body size, habitat, prey base, and genetic signature. Both skull morphology and body size of Eastern Wolves are intermediate to Great Lakes-Boreal Wolves and Eastern Coyotes (Kolenosky and Standfield 1975; Schmitz and Kolenosky 1985; Sears *et al.* 2003; Theberge and Theberge 2004; Rutledge *et al.* 2010c**,** 2010d; Benson *et al.* 2012). Long before genetics was used to identify species, Kolenosky and Standfield (1975) categorized wolves in Algonquin Provincial Park (hereafter. 'Algonquin Park') separately from surrounding *Canis* types based on body size and skull morphology. Their distribution map of *Canis* in Ontario has since been supported by the patterns identified with molecular genetic techniques (Rutledge 2010a; Figure 2).

Figure 1. Photograph of Eastern Wolf from Algonquin Provincial Park. © Michael Runtz, used with permission.

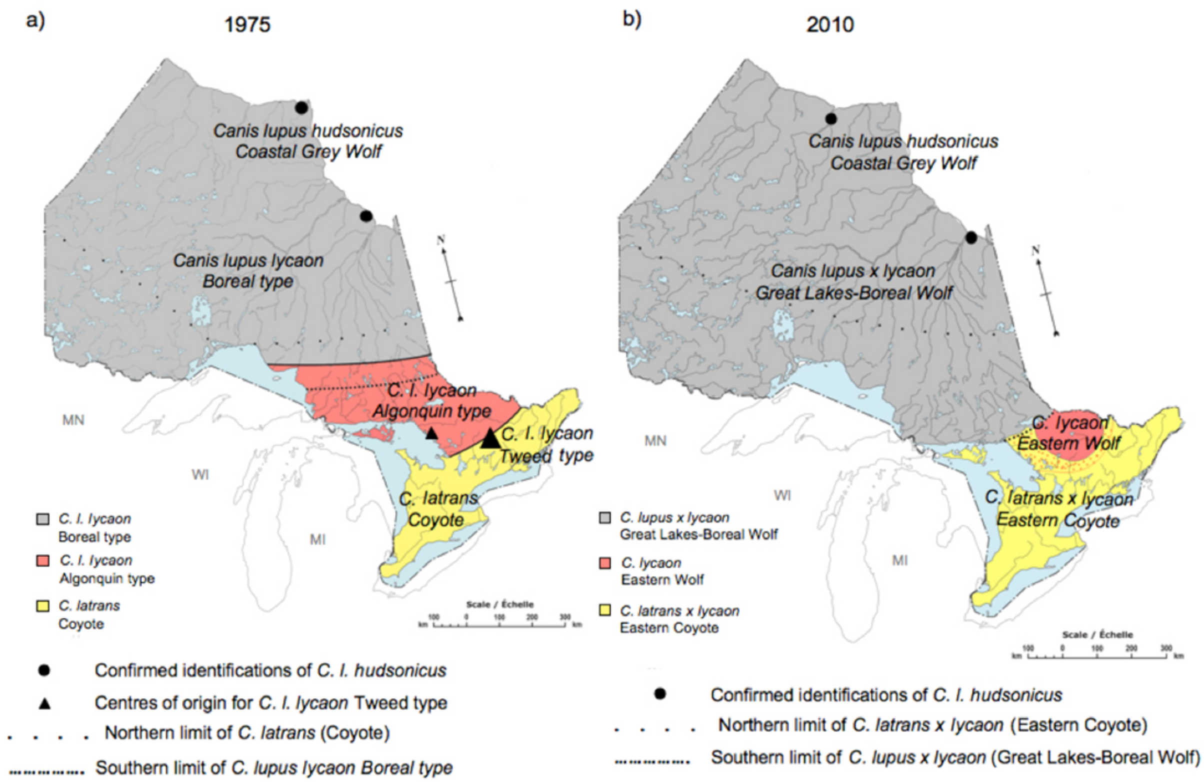

Figure 2. Distributions of types of *Canis* species in Ontario, as proposed by: a) Kolenosky and Standfield (1975) based on skull morphology and body mass, and; b) proposed by Rutledge (2010) based on genetics and body mass. Kolenosky and Standfield (1975) gave poorly defined limits for the *C. l. lycaon* Tweed type, but indicated a centralized area indicated by the triangles, with the larger triangle indicating higher frequency of occurrence. They also suggest that agricultural areas were inhabited by the Coyote (*C. latrans*), presumably the western coyote. Very few samples of *C. l. hudsonicus* were available in either study, but in both cases they appear to represent a Gray Wolf subspecies that inhabits the Hudson and James Bay coastal areas. The stippled area overlapping the central Eastern Coyote range in b) indicates the approximate area where Algonquin Park Eastern Wolves have been documented in Ontario, although some disperse east into Québec. The more northerly limit of Eastern Coyotes indicated in b) is based on confirmed Eastern Coyotes in Nakina, Ontario. The Great Lakes-Boreal Wolf range extends into Manitoba, Québec, and the western Great Lakes states of Minnesota (MN), Wisconsin (WI), and Michigan (MI) (from Rutledge 2010a,b).

Eastern Wolves are typically < 30 kg (Theberge and Theberge 2004). Based on data collected in Algonquin Park from 2002 - 2007, female average yearling weight is 18.1 kg and female average adult weight is 24.2 kg, whereas male average yearling weight is 23.5 kg and average adult weight is 29.3 kg. Jolicoeur and Hénault (2010) reported the mean weight of *Canis* found in Réserve faunique La Papineau-Labelle (hereafter, 'Papineau-Labelle Reserve') as 24.6 kg (±0.7 SE) for males and 22.2 kg (±0.9 SE) for females. In Parc national de la Mauricie (hereafter, 'La Mauricie Park'), adult female *Canis* have an average weight of about 28.7 kg, with shoulder height of 71.8 cm and an average male adult weight of approximately 44.5 kg, with shoulder height of 81.2 cm (Villemure and Festa-Bianchet 2002). Although sample sizes were low (3 females, 2 males), these sizes are larger than those estimated for Eastern Wolves and likely include Great Lakes-Boreal Wolves in the sample. Average adult shoulder height for Eastern Wolf from the Algonquin Park region is

63.8 cm for females and 70.0 cm for males (Patterson 2011b, pers. comm.). Eastern Wolves are longer (from tip of nose to base of tail) than Eastern Coyotes, with average Eastern Wolf female length of 109.3 cm (± 1.3 SE) and average male length of 113.0 (± 1.8 SE) (Benson *et al.* 2012). Body size is important in predators because morphological characteristics affect energetic requirements and influence the size of prey that wolves can effectively hunt (Carbone *et al*. 1999; MacNulty *et al.* 2009).

Coat colour is not a reliable descriptor of the different *Canis* species because of the variability in pelage among *Canis*. However, Eastern Wolves (Figure 1) typically have coats with more reddish-brown/tawny colouration and reddish forelegs, when compared to Gray Wolves and Great Lakes-Boreal Wolves.

Population Spatial Structure and Variability

Population (genetic) structure of *Canis* in the region varies due to the introgression of *Canis latrans*, and *C. lupus* genes into the remaining Eastern Wolf population. The Canid types are separated based on use of Q values, which represent the probability of belonging to a cluster, as identified in the genetic analysis program STRUCTURE 2.3 (Hubisz *et al*. 2009; Appendix B).

The amount of variation within the Eastern Wolf population is unknown.

Designatable Units

A single designatable unit is recommended for the Eastern Wolf. The definition of the Eastern Wolf is based, in part, on genetic differentiation from other *Canis* in the region (*i.e.,* Q ≥0.8; Appendix B) and individuals with Q values exceeding this threshold are considered similar.

Special Significance

Existing Eastern Wolves likely represent a relict population that once inhabited the eastern temperate forests of North America, including the southern regions of Ontario and Québec, prior to the arrival of European settlers (Rutledge *et al.* 2010d; Kyle *et al.* 2006; Figure 3). Clearing of land, invasion of non-endemic Coyotes, and targeted persecution of large canids may have pushed Eastern Wolves north into Algonquin Park and south-central Quebec, which probably represents a refugium at the northern limit of their historical distribution.

a)

b)

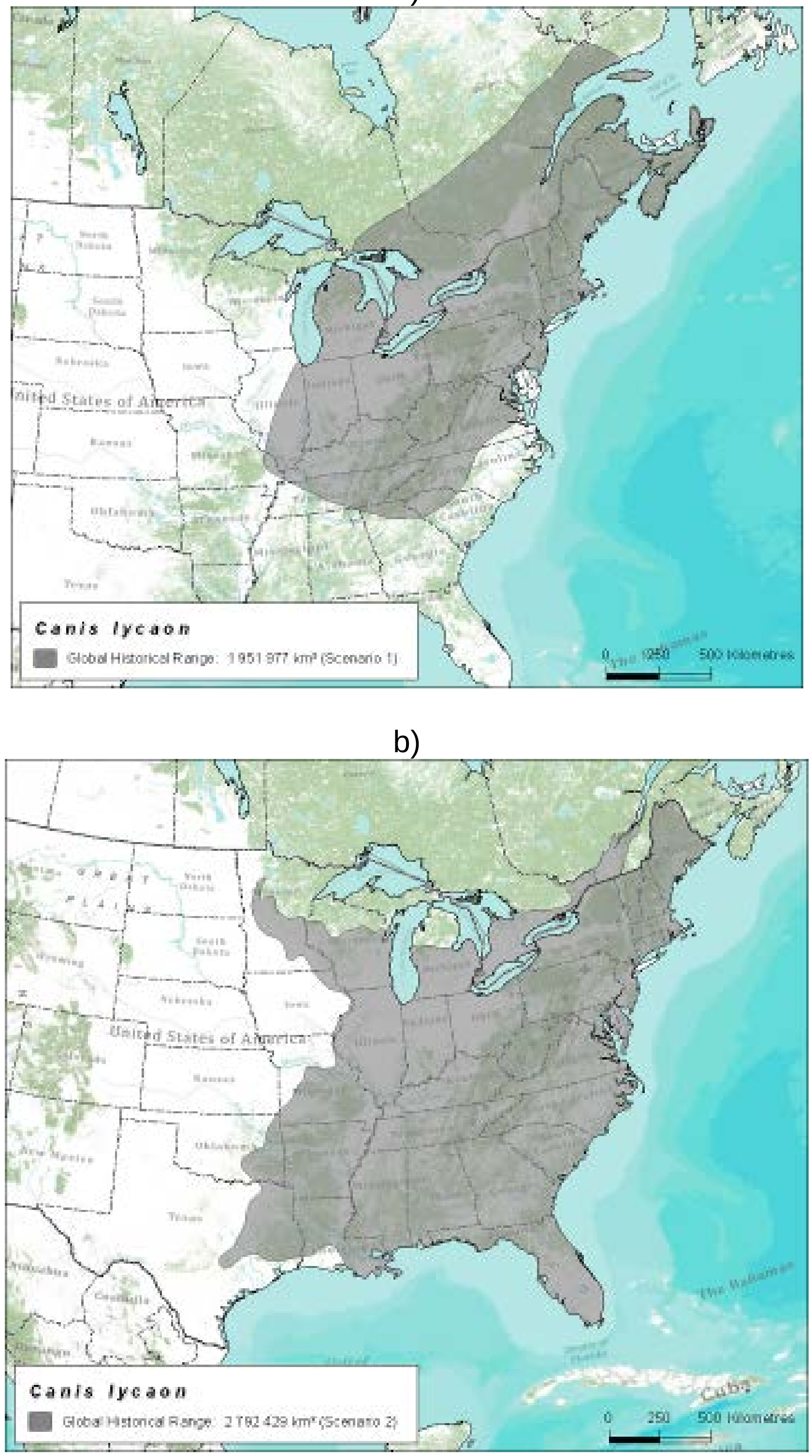

Figure 3. Global historical Eastern Wolf range. Gray = Global range. a) Scenario 1 based on Nowak (1995) and Leonard *et al.* (2005). b) Scenario 2 based on Wilson *et al.* (2000) and Rutledge *et al.* (2010d). Delineation of the eastern temperate forests from CEC (1997).

The current socio-economic importance of Eastern Wolves is difficult to quantify, but, of note, an estimated > 162,000 people have ventured to Algonquin Park to participate in the educational Wolf Howl Program since the 1960s (Steinberg pers. comm. 2013). This program provides a unique educational and recreational component of tourism in Ontario.

The value of Eastern Wolf to trappers is unknown. Large canids are trapped and hunted within the range of the Eastern Wolf (see **Legal Protection and Status**) but the number of pelts from Eastern Wolves is unknown because pelts of mixed/unknown genotypes typically are grouped together for auction.

The Eastern Wolf also has special significance because it may be the last significant wild population of the Red Wolf, a critically endangered species in the United States (see Taxonomic Validity; Appendix A). In addition, larger carnivores influence ecosystems (Chapron *et al.* 2008; Beschta and Ripple 2009, 2010), and the role of the Eastern Wolf in the region likely differs from that of the smaller Eastern Coyote, and the larger Gray Wolf.

DISTRIBUTION

Global Range

The Eastern Wolf, as described here, is not currently found in the United States, although it probably did historically range across the eastern temperate forest region of North America (Figure 3) (Wilson *et al.* 2000; Kyle *et al.* 2006; Rutledge *et al.* 2010d).

The historical distribution for this species is difficult to assess because of the limited availability of fossil information and the varying interpretations of Eastern Wolf taxonomy. If one accepts the interpretation that the Eastern Wolf and the Red Wolf were historically the same species, then both genetic data and the fossil record suggest that the Eastern Wolf/Red Wolf historically occupied all of the eastern temperate forests of North America (Wilson *et al.* 2000; Rutledge *et al.* 2010d), an area nearly 3 million km^2 (Figure 3). This range extended west just beyond the Mississippi River, south to Florida, and east to the Atlantic coast. Although Red Wolves historically occupied regions west of the Mississippi River in Louisiana and Texas (where the captive breeding population was collected), the introgression of Coyote, Gray Wolf, and possibly Dog genes in the Red Wolf population suggest these regions were historical hybrid zones. Thus, the Mississippi River may have been a natural geographic barrier that presumably limited hybridization eastward. Nowak (1995) suggested a smaller, more northern historical range for Eastern Wolves (Figure 3a), independent of Red Wolves.

Presently, Eastern Wolf, as defined in this report (Q≥0.8; see Appendix B), are not believed to be present outside Canada. Under the 3-species hypothesis, the Red Wolf and Eastern Wolf likely were the same species but have since differentiated enough due to introgression from Dog and Coyote genes during the breeding program (see Appendix A) that they no longer fit the Q≥0.8 threshold used in this report (see Appendix B). The Eastern Wolf mtDNA found in samples in Minnesota and area are considered hybrids of Eastern Wolf and Gray Wolf (= Great Lakes-Boreal Wolf, or Great Lakes Wolf) (see Appendix A).

Canadian Range

The historical Canadian range of Eastern Wolves likely included the Deciduous Forest region of southern Ontario and Québec, but may have overlapped into the southern part of the Great Lakes-St. Lawrence Forest region. Nowak (1995) suggested a northern range that included the Great Lakes-St. Lawrence Forest region and possibly the Acadian Forest (Figure 3a). The historical Canadian range is therefore estimated at between 112,610 – 500,533 km^2.

The present Canadian range of the Eastern Wolf (Figure 4) is based on genetic analysis of *Canis* specimens sampled across much of the Great Lakes region and from Manitoba to the Maritime Provinces (see **Search Effort** and Taxonomic Validity). The distribution of the Eastern Wolf is based on the available literature that relies on genetic analyses (see Appendix B). Most *Canis* individuals recorded outside the core range are identified primarily as Great Lakes-Boreal Wolves or Eastern Coyotes (Stronen *et al.* 2012; Rutledge *et al.* in prep.).

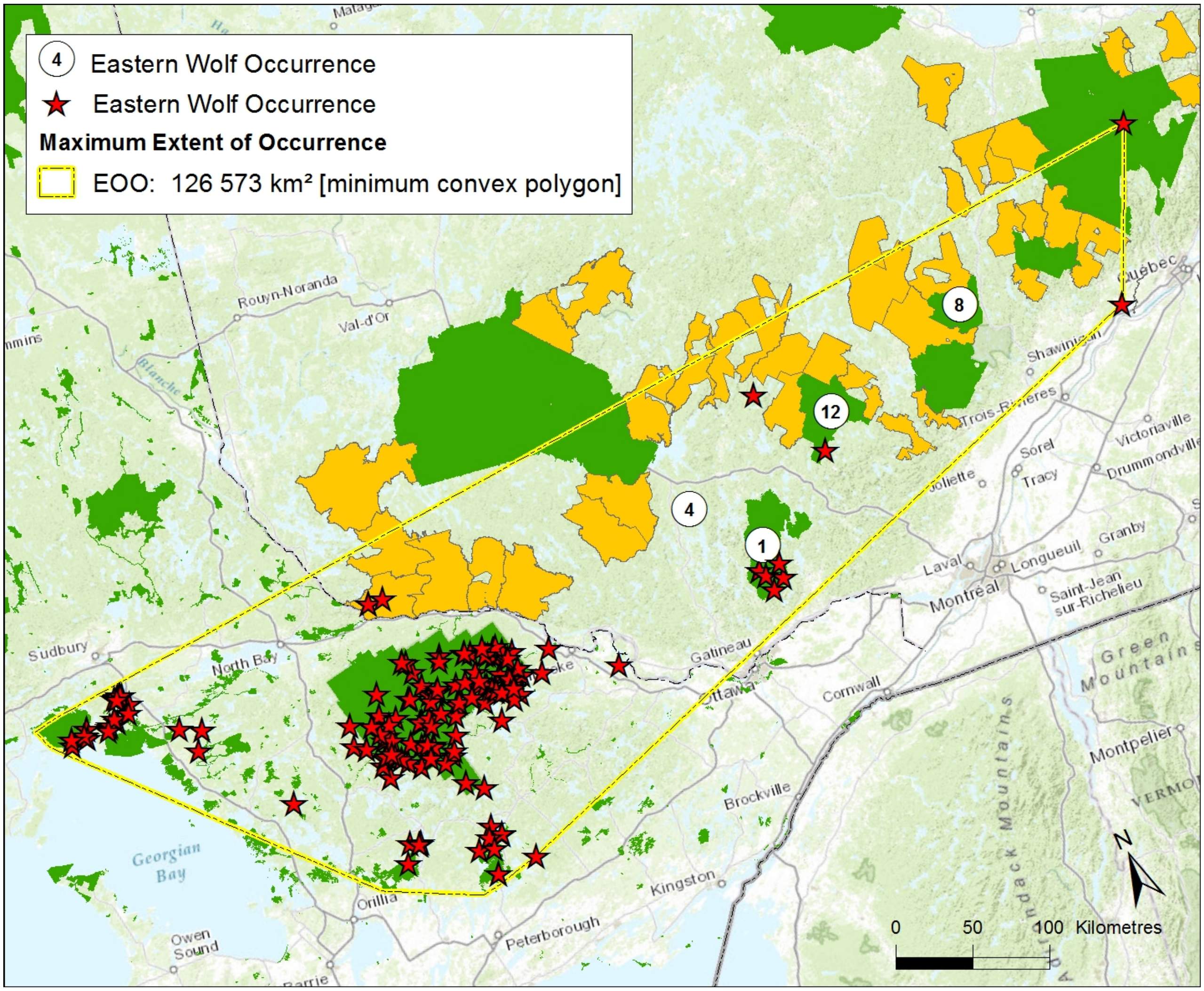

Figure 4. Extent of occurrence (EOO) of Eastern Wolves with locations of Eastern Wolf based on a methodology common to various publications (i.e., Rutledge *et al*. 2010a, 2010b, 2010c; Rutledge and White 2013, 2014), and indicated by the star symbol, or from Rogic *et al*. (2014), Hénault unpub. data or Tessier unpub. data), and indicated by the circle symbol. The number within the circles indicates the number of individuals and indicates the approximate location of the specimen. Protected areas and reserves are identified by dark shading and controlled exploitation zones ('Zec') are identified by the lighter shade.

Manitoba

Although an Eastern Wolf mtDNA control region haplotype and ATPase haplotype (C3/Ccr13/GL2; Catp13) have been found in Manitoba Wolves (Stronen *et al.* 2010; Rutledge *et al.* 2010b), most wolves in Manitoba have Gray Wolf mtDNA (Stronen 2009; Stronen *et al.* 2010). Stronen *et al.* (2012) examined nuclear microsatellites but only included eight individuals from Algonquin Park, which is considered to be likely insufficient for cluster identification in the presence of gene flow (Fogelqvist *et al.* 2010), and therefore would have likely been unable to identify Eastern Wolf by the same definition used for the Algonquin Park subpopulation (see papers by Rutledge, Benson; Appendices A, B). However, evidence of Eastern Wolf genes (termed 'new world mtDNA', separate from old world Gray Wolf mtDNA) were found across the Québec to Saskatchewan region, which is interpreted under the 3-species hypothesis as evidence of Great Lakes-Boreal Wolf (Great Lakes Wolf)) being hybrids from Eastern Wolf x Gray Wolf. In general, Manitoba Wolves cluster more closely with Great Lakes-Boreal Wolves of the Great Lakes states, northern Ontario, and northern Québec, although with greater influence from Gray Wolves from the Northwest Territories (Wheeldon 2009). Wolves from Manitoba are considered different from the Eastern Wolves of Algonquin Park (Wheeldon 2009; Wilson *et al.* 2000).

Ontario

The distribution of Eastern Wolf in Ontario is from west of Algonquin Park to the Ottawa Valley, and south to Frontenac Park. Distribution is discontinuous though, with records mainly confined to various protected areas (Figure 4).

The most northern limit of Eastern Wolves in Ontario appears to be Killarney Park and regions south of Sudbury between Killarney Park and Hwy 69 (Rutledge *et al*. in prep.). Based on size, morphology and telemetry data, Eastern Wolves appear to be resident in Queen Elizabeth II Wildlands Park, although genetic analysis is still required for confirmation (Patterson pers. comm. 2014). In the Magnetawan region, west of Algonquin Park, animals were largely admixed, although a few (<10) appeared similar to *Canis* from Algonquin Park (Wilson *et al.* 2009). Most recently, Benson *et al.* (2012) analyzed 342 *Canis* in and around Algonquin Park and documented three Eastern Wolves in Wildlife Management Unit (WMU) 47, and one in WMU49 but found that animals outside Algonquin Park and Kawartha Highlands Park (*i.e*., within WMU47 and WMU49) were predominantly Eastern Coyotes or admixed individuals.

Twelve Eastern Wolves have been identified in Kawartha Highlands Park (376 km^2) south of Algonquin Park (Benson *et al.* 2012). Although there is some evidence that reproducing Eastern Wolves have established themselves in WMU49 (Benson *et al*. 2012), Eastern Coyotes and admixed individuals are more prevalent there, likely due to higher mortality of Eastern Wolves outside protected areas (Benson *et al*. 2012).

Québec

Eastern Wolf in Québec were identified by two methods. The methods are very similar except that the analyses by Stronen *et al*. (2012), Rogic *et al*. (2014), Henault (unpub. data), and Tessier (unpub. data) used fewer samples from the Algonquin Park area, resulting in a broader definition of Eastern Wolf and thus includes more samples that would be labelled as admixed animals than if the method in Rutledge and White (2013, 2014) was used. Results from both methods are presented (Figure 4) but the method used by Rutledge and White (2013, 2014) was used in both Ontario and Québec and is given priority in establishing the boundaries of the extent of occurrence (EO). Samples from the other method located beyond the EO are not included here. More work on the distribution of Eastern Wolf would help define the distribution of Eastern Wolf in Québec.

In Québec, 16 Eastern Wolves were identified from 457 *Canis* samples using the same techniques used to identify *Canis* individuals from Ontario (Rutledge and White 2013, 2014; Table 1; Figure 4). For example, five Eastern Wolves were located in Papineau-Labelle Reserve (1628 km^2), two were located north of Mattawa, one was found in the Réserve faunique Rouge-Matawin (Rouge-Matawin Reserve) and another was sampled northwest of the Reserve. Single Eastern Wolves were found in the Réserve faunique des Laurentides (Laurentides Wildlife Reserve), and near Saint-Basile, Québec (Figure 4). A sample of a single male trapped south of the St. Lawrence River in Québec near the village of Sainte-Marguerite-de-Lingwick had previously been identified as an Eastern Wolf because its microsatellite profile was consistent with an Eastern Wolf from Algonquin Park (Villemure and Jolicoeur 2004), but recent work has established it as admixed, and not an Eastern Wolf (Rutledge and White 2014).

Table 1. Sampling effort and number of Eastern Wolves found. Eastern Wolf occurrence is based on an assignment of Q≥0.8 in the program STRUCTURE where individuals were genotyped at 12 autosomal microsatellites. Source data are from literature noted below.

Location	Sample Size	# Eastern Wolves (Q≥0.8)	% Eastern Wolves
Manitoba[1]	36	0	0
Ontario[2,3,4,5]	558	154	28
Québec[6,7]	457	16 (+25[a])	3
Total	1051	170 (+25[a])	16

[1]Wheeldon 2009; [2]Rutledge *et al.* In Review CJZ; [3]Rutledge *et al*. 2010c; [4]Benson *et al*. 2012; [5]Wheeldon *et al*. 2013; [6]Rutledge and White 2013, 2014; [7]Villemure and Jolicoeur 2004.

[a] An additional 25 samples were identified in Québec using a different methodology (Rogic *et al*. 2014; Hénault unpub. data; Tessier unpub. data). The sample sizes in these analyses are not included in the sample size column.

The single occurrences are possibly vagrants because it is unknown if these animals represent an undersampled subpopulation of resident animals, or whether they are dispersers. They are included as part of the range of Eastern Wolf until further sampling confirms other Eastern Wolves are not in the area.

The method used by Rogic *et al*. 2014, Tessier (unpub. data) identified 25 additional records during approximately the last 10 years (Figure 4). Eight Eastern Wolf were identified in La Mauricie Park or within 10 km of the boundary (Tessier unpub. data). Wolves in La Mauricie Park had previously been classified as Eastern Wolves, based largely on morphology, the distribution proposed by Nowak (1995), and the presence of an Eastern Wolf mtDNA haplotype (Villemure 2003; Villemure and Festa-Bianchet 2002; Villemure 2011, pers. comm.). Adult wolves in La Mauricie Park are similar in size to Great Lakes-Boreal Wolves and it is likely that several *Canis* types reside there (Villemure 2003).

Similarly, Rogic *et al*. (2014) and Tessier (unpub. data) identified 12 Eastern Wolves in Parc national du Mont-Tremblant ('Mont-Tremblant Park') based on recently collected samples analyzed with genetic analysis in Stronen *et al*. (2012). There also are four recent records from the area north of Mont-Laurier, and one record near Québec City (Hénault unpub. data).

Based on morphological features that included cranial measurements, Jolicoeur and Hénault (2010) suggested that two types of wolves are found in Québec, a smaller wolf (average weight 23 kg) consistent with the distribution of White-tailed Deer (*Odocoileus virginianus*; hereafter 'Deer'), and a larger wolf within the distribution of Moose and Caribou (*Rangifer tarandus*) (average weight 30 kg).

Grewal *et al.* (2004) suggested that wolves in Réserve faunique La Vérendrye (La Verendrye Reserve) were more similar to samples from Abitibi-Temiscamingue, than samples from Algonquin Park, but still thought they were more genetically similar to those from Algonquin Park than areas in southeastern Ontario. However, this conclusion was not based on the more sensitive approach of Bayesian clustering in STRUCTURE, but rather on loosely interpreted R_{ST} and F_{ST} values determined on data from eight microsatellites.

Maritime Provinces

Nowak (1995) suggested a historical presence of Eastern Wolves in the Acadian Forest Region of New Brunswick and Nova Scotia and a northern limit was proposed by Nowak (2009) that includes the Great Lakes-St. Lawrence Forest Region from the southeast corner of Lake Superior, through Ontario and Québec to the Gaspé Peninsula (Figure 3a). A *Canis* type existed in the Gaspé Peninsula and Maritime provinces but was extirpated in the 19th century; the taxonomy is unknown because of a lack of any specimens (Lohr and Ballard 1996). Eastern Coyote are now common in the region but no microsatellite profiles specific to the Eastern Wolf have been found in the population (Way *et al*. 2010). Therefore, the current Canadian range of the Eastern Wolf does not include the Maritime Provinces.

Extent of Occurrence and Area of Occupancy

The current extent of occurrence, based on the minimum convex polygon connecting the points of observed Eastern Wolf occurrence, is estimated to be 126,573 km^2 (Figure 4). The extent of occurrence (EOO) is based on records identified from the method used for both Ontario and Québec (Rutledge *et al*. 2010c; Benson *et al*. 2012; Rutledge and White 2013, 2014). This area also contains most of the records identified by a similar method used by Rogic *et al*. 2014, and Tessier and Henault, unpub. data for Québec. Records identified by Stronen *et al*. (2012) and Rogic *et al*. (2014) outside the EOO are not included (see 'Quebec' section of **Canadian Range**). Single records are difficult to assign as resident or vagrant animals but are included in the EOO because the animal may be evidence of a resident population.

The area of occupancy is 29,472 km^2 and is based on the size of the sites where the Eastern Wolf has been recorded. The size of each site is used because these sites are protected areas and *Canis* mortality is less (see Mortality Rates and **Threats**), or likely less in the case of Québec Wildlife Reserves, where hunting and trapping are allowed, but development and human density typically is lower when compared to non-protected areas.

Search Effort

Many studies have used *Canis* samples from Eastern Wolf range and compared them to samples from the Great Lakes region, the southern US, and parts of Canada. An unknown number of the same samples are reused in different studies but sampling appears to be intensive and extensive (Figure 5). Wheeldon (2009) analyzed 627 canid samples (at 12 nuclear microsatellites) from Northwestern Ontario (n=87); Northeastern Ontario (n=93); Michigan (n=90); Wisconsin (n=48); Minnesota (n=53); Northwest Territories (n=56); Manitoba, n=36 (north of Duck Mountain National Park, n=11; Duck Mountain National Park, n=13, Riding Mountain National Park, n=12); Québec, n=34 (western Québec, n=24; eastern Québec, n=10); Algonquin Park, n=54; Frontenac Axis, n=52; Texas, n=24. Way *et al.* (2010) analyzed 583 *Canis* samples from Northwest Territories, Ontario (including Algonquin Park), Québec, New Brunswick, and the eastern United States. In Manitoba, Stronen (2009) conducted analyses of 221 wolf faecal and hair samples identified as different individuals from Riding Mountain National Park and the Duck Mountains collected from 2003 – 2005.

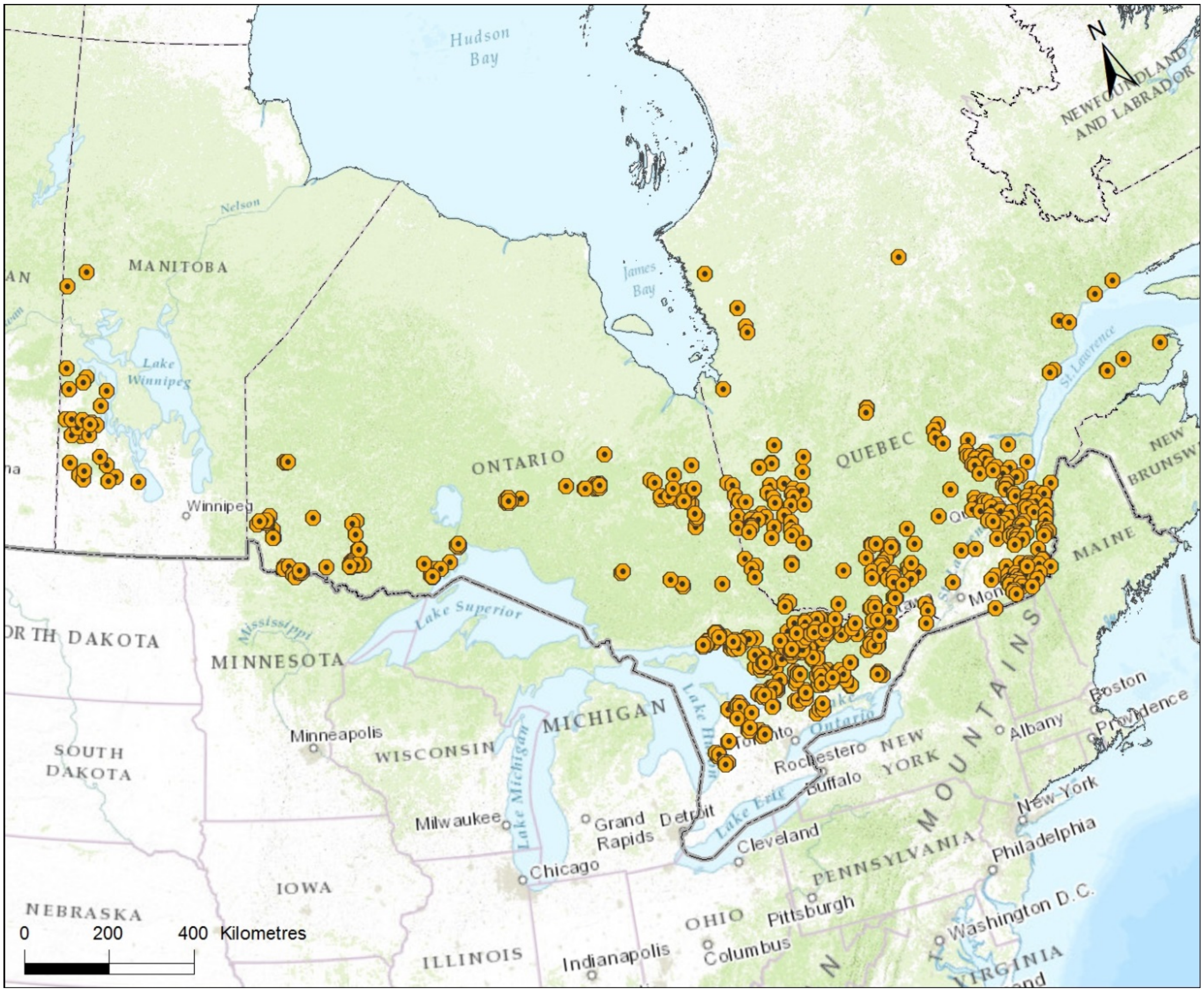

Figure 5. Location of samples used in identifying the distribution of Eastern Wolf in Canada (see Search Effort for details on samples).

Most sampling of Eastern Wolves in Ontario has been part of a larger study of *Canis* species conducted by the Ontario Ministry of Natural Resources since 2002. Algonquin Park has been sampled extensively as a result of ongoing wolf research in the Park. Between 1909 – 1958, Park policy promoted a targeted wolf eradication program that ceased to allow a government research project on the ecology of wolves. As part of the project, Pimlott *et al.* (1969) lethally sampled 106 wolves from the Park, and 19 of those were analyzed by Wilson *et al*. (2000) at the mtDNA control region. Seventeen of the samples described in Pimlott *et al.* (1969) have been genetically analyzed with autosomal microsatellites (Rutledge *et al.* 2011). Grewal *et al*. (2004) analyzed 102 blood and tissue samples from 27 of the 35 known wolf packs in Algonquin Park sampled between 1987 - 1999. Rutledge *et al.* (2010c) analyzed 128 samples from Algonquin Park in combination with 51 from northeastern Ontario and 38 from the Frontenac Axis in southern Ontario. Wilson *et al.* (2009) analyzed 269 samples from 6 geographic regions including southern Ontario, Magnetewan west of Algonquin Park, and northern Ontario.

Stronen *et al*. (2012) used 109 samples from the Canadian Prairies and 154 from Québec, plus 8 from Algonquin Park, to determine the extent of Eastern Wolf genes from Saskatchewan to Québec. vonHoldt *et al*. (2011) used a sample of 208 wolves from a worldwide sample, plus 57 Coyote from North America, and other *Canis*, including domestic dog, to assess issues of hybridization. Only three samples were from the extant range of Eastern Wolf; 2 samples were from Algonquin Park, and 1 from southern Québec.

A total of 457 samples, collected from across Québec (Figure 4), were analyzed with Ontario samples, using the same technique, and interpretation as had been used in Ontario (Rutledge and White 2013, 2014). Rogic *et al*. (2014) analyzed 15 samples (14 tissue, 1 fecal) collected between 2007 – 2013 in and around Mont-Tremblant Park, and compared them with samples from Stronen *et al*. (2012).

Numerous research projects on the ecology (e.g. food habits, survival, movement, etc.) of Eastern Wolf have been conducted in Algonquin Park and surrounding areas over the last 50 years (Pimlott *et al*. 1969; Forbes and Theberge 1995; Forbes and Theberge 1996b; Wydeven *et al*. 1998; Mills *et al.* 2008; Loveless 2010; Rutledge *et al.* 2010e; Benson *et al.* 2013b, 2014). In Québec, ecological studies also have been conducted in areas containing Eastern Wolf, such as Papineau-Labelle Reserve (Potvin 1988; Potvin *et al*. 1988, 1992a, b). The degree to which data are specific to Eastern Wolf in these areas is unknown.

HABITAT

Habitat Requirements

Research on habitat use by *Canis* in Algonquin Park, and Papineau-Labelle Reserve suggests that the Eastern Wolf is not restricted to any particular forest type (Pimlott *et al*. 1969; Potvin *et al*. 1988; Theberge and Theberge 2004). The definition of habitat (realized niche) includes competition, predation, prey availability, and den sites. The availability of prey, and mortality, appear to be important habitat features, with evidence that Eastern Wolf are most abundant in areas with abundant prey, such as Deer, and low levels of human-related mortality (see **Interspecific Interactions** and **Threats**). The ecological environment and management practices in Algonquin Park represent the most suitable habitat for Eastern Wolves because prey is available and the large size of the Park (7,571 km^2), plus the surrounding zone where *Canis* are free from harvest (6,340 km^2), creates the largest number of Eastern Wolf packs exposed to low mortality levels and the least amount of Coyote introgression (Benson *et al.* 2012). In Québec, sites containing Eastern Wolf also are mainly protected areas where prey populations likely are abundant, although mortality rates may be higher because wolf harvest is permitted in some sites (e.g., Papineau-Labelle Reserve (see **Legal Protection and Status**).

Pack size is likely associated with territory size and both may be linked to prey density. Eastern Wolves have an average territory size of approximately 190 km^2 (±SD 88, n=12; Loveless 2010) in Algonquin Park and 199 km^2 (± SE 16, n=19) in Papineau-Labelle Reserve (Potvin 1988). The upper limit of Eastern Wolf pack size ranged from 9 - 14 in Algonquin (Loveless 2010; Theberge and Theberge 2004) and 10 in Papineau-Labelle Reserve (Potvin 1988). Due to their energetic requirements, Eastern Wolves require large prey such as Deer, which are abundant in moderate to high density in the southern part of Ontario (Cervid Ecological Zone E3; OMNR 2009), and Beaver, which are found across Ontario primarily in forested regions but whose abundance fluctuates with habitat suitability (Fryxell 2001). Eastern Wolves may shift from Deer to Moose through the winter via predation (Loveless 2010) or scavenging on Moose killed in association with Winter Tick (*Dermacentor albipictus*) infestations (Forbes and Theberge 1992).

Den sites are an important habitat feature but dens have been located in a wide range of soil and forest types and are not expected to be limiting factors. In the eastern part of Algonquin Park, den and rendezvous sites are located primarily in pine (*Pinus* spp.) forests (Norris *et al.* 2002) possibly due to the sandy, easily excavated soil. Pups are relocated by adults after human disturbance but disturbed dens are often used in subsequent years (Argue *et al.* 2008). Various rendezvous sites are used into the fall (Mills *et al.* 2008). Both den and rendezvous sites tend to be located in conifer-dominated landscapes near a permanent water source (Pimlott *et al.* 1969; Norris *et al.* 2002).

Habitat Trends

The amount and extent of vegetative habitat supporting Deer populations likely is increasing in parts of Eastern Wolf range; previously agricultural-dominated landscapes in southeastern Ontario are succeeding into forest at an estimated rate of 1.9% per decade (Lancaster *et al.* 2008) and may represent improved habitat for Eastern Wolves. Forested landscapes with minimal road networks are still available directly south, west, and east of Algonquin Park, as well as large parts of the range in Québec (Figure 6). The smaller areas in the southern reaches of Ontario may contain only one pack, and likely are too small to sustain viable wolf populations (Benson *et al*. 2014). A forested corridor with lower road density connects Bon Echo Provincial Park to Frontenac Provincial Park and the Charleston Lake area west of Algonquin Park. The Queen Elizabeth II Wildlands Park probably represents prime Eastern Wolf habitat, and recent work suggests Eastern Wolves are present (Patterson pers. comm. 2014). In Algonquin Park, fire protection and relatively low intensity forest harvest could negatively impact the future amount of early-succession associated species such as Deer and Beaver (Quinn 2004, 2005).

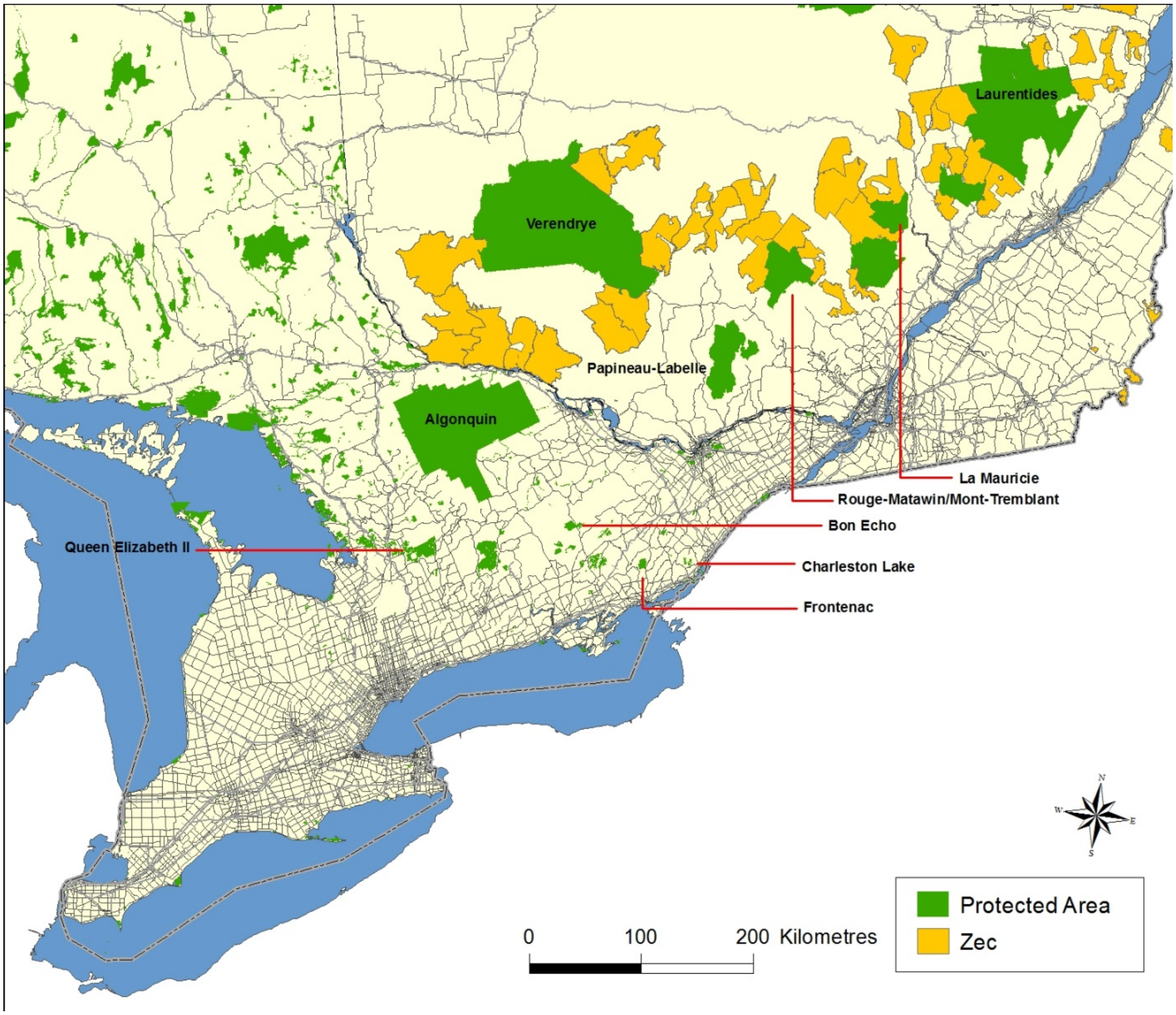

Figure 6. Location of protected areas and major paved roads within the range of Eastern Wolf. Protected areas vary in degree of protection from hunting and trapping, with wolf harvest not permitted in Algonquin, Queen Elizabeth II, Mont-Tremblant, and La Mauricie parks. Reserves and controlled exploitation zones ('*Zec'*) areas are subject to hunting and trapping. Major paved roads are indicated by black lines.

Potential expansion habitats include forested regions extending from Algonquin Park that have limited human-altered landscapes, few road networks/low traffic volume, and protection from hunting and trapping. These areas include regions north to Killarney Park, west to Georgian Bay, south to Hwy 7 and perhaps along the Frontenac Axis through the Algonquin to Adirondack region (although increasing road networks and urbanization may present difficulties in that area), and east across southern Québec's parks and faunal reserves to Saguenay Fjord Park.

Expansion of Eastern Wolves will not occur without protection from hunting and trapping throughout its range because juvenile dispersers are more susceptible to harvest (Theberge and Theberge 2004). Four of five radio-tagged juveniles died from trapping < 1 year after dispersal to areas outside Algonquin Park, and Eastern Wolf were more vulnerable to harvest than other *Canis* types outside Algonquin Park (survival rates of 33% for Eastern Wolf, compared to 66% for Eastern Coyote, and 85% for *Canis* within Algonquin Park (Benson *et al.* 2014)). As well, high harvest rates increase hybridization with Eastern Coyotes (Rutledge *et al.* 2011; Benson *et al.* 2014).

Wolves, in general, may benefit from roads because of increased hunting efficiency (Whittington *et al*. 2011; Lesmerises *et al*. 2012) but populations can decline if increased access for hunters and trappers facilitates unsustainable harvest rates (Mech *et al*. 1988; Person and Russel 2008). A road density of < 0.4 – 0.7 km of road per km^2 and human density of < 4 per km^2 have been suggested as necessary to support large Canids, if mortality from humans is a concern (Wydeven *et al.* 1998). In most of southeastern Ontario, road density is > 0.6 km per km^2 (Buss and deAlmeida 1997; Figure 6) and in southern Ontario road length increased from 7,133 km in 1935 to 23,806 km in 1965, and to 35,637 km in 1995 (Fenech *et al.* 2000). This trend may limit Eastern Wolf dispersal southward.

BIOLOGY

Much of our knowledge of wolves derives from studies on Gray Wolves or Great Lakes-Boreal Wolves (e.g. Mech and Boitani 2003). Substantially less information is available on Eastern Wolves. The information presented here is primarily a synthesis of research conducted on Eastern Wolves in Algonquin Park, as well as research from Québec (e.g., Papineau-Labelle Reserve) where Eastern Wolf has been recorded.

Life Cycle and Reproduction

Early life stages are divided into: 1) denning (age < 6 weeks); 2) early rendezvous (age 6 – 12 weeks); 3) late rendezvous (age 12 - 17.9 weeks); and 4) rendezvous abandonment (age ≥18 weeks) (Mills 2006). Pups are born in late April to early May. At 6 - 8 weeks they are moved from the natal den to an initial rendezvous site. Throughout the summer, pups are moved to subsequent rendezvous sites that occur at increasing distance from the den (Mills *et al.* 2008) until the sites are abandoned in fall. Eastern Wolves hunt in packs but pups do not hunt until they are about 18 weeks old and when final rendezvous sites are abandoned.

Generation Time

The average life span of wolves has been reported as 4 or 5 years (Fuller *et al.* 2003) with some animals reaching at least 15 years (Theberge and Theberge 2004). Survival rates for adults were 63-70% in the late 1980s – early 1990s (Forbes and Theberge 1995). Average annual survival rate ($\hat{s}$) of pups is estimated at 0.749 (±0.061 SE) in eastern Algonquin Park and 0.246 (±0.073 SE) in western Algonquin Park (Benson *et al.* 2013b). The lower survival in western Algonquin Park is influenced by low Beaver density and unavailability of wintering Deer. Survival of yearlings and adults in Algonquin Park was higher ($\hat{s}$ = 0.852 (±0.05 SE)) than pup survival (Benson *et al.* 2014). Using these data, life expectancy (LE) (calculated as $LE = -1/(\ln(\hat{s}))$, where $\hat{s}$ is the average annual survival rate), of pups is between 0.7 and 3.5 years, whereas yearlings and adults have a life expectancy of 6.2 years. Females do not typically breed before 2 years and therefore the generation time is likely to be approximately 3.5 years.

Eastern Wolves typically have a single, unrelated breeding pair within each pack. Pimlott *et al*. (1969) documented that 59% of all female adults (≥ 2 years) sampled in Algonquin Park had produced at least one litter. Litters are produced annually and range between 2 - 7 pups, with an average of 4.9 (Mills *et al.* 2008). Sex-ratio of 5.5 week old pups is 1:1 and mortality is not different between sexes (Mills *et al.* 2008). Vucetich and Paquet (2000) suggested the average age of Eastern Wolves in Algonquin Park prior to the harvest ban was 2 - 3 years old, which is lower than the post-ban average age of 5 years. Based on capture statistics in Algonquin Park from 2002 - 2007, the proportion of pups in the population is estimated at 39.1%; yearlings and adults comprise 15.0%, and 45.9%, respectively (Patterson, unpub. data).

Most Eastern Wolves exist in packs that are highly social and territorial. Average pack size in Algonquin Park and Papineau-Labelle Reserve is around six animals (Potvin 1988; Forbes and Theberge 1996b). Wolf social structure is important for effective resource use (Sand *et al.* 2006; Stahler *et al.* 2006; Loveless 2010), pup survival (Brainerd *et al.* 2008; Schmidt *et al.* 2008), avoidance of incestuous mating (vonHoldt *et al.* 2008), and precluding hybridization with Coyotes (Rutledge *et al.* 2011).

When naturally regulated, Eastern Wolves live in family-based social packs with little evidence of inbreeding. Rutledge *et al.* (2010e) documented unrelated males joining packs and becoming the breeder (after the known breeding male could no longer be located with telemetry equipment), and daughters of breeding females were identified as subsequent breeders with unrelated males within their natal pack. When influenced by high human-caused mortality, Eastern Wolf packs become fractured with higher adoption of unrelated individuals (Grewal *et al.* 2004) and more prevalent hybridization with Eastern Coyotes (Rutledge *et al.* 2011).

Mortality rates

Based on research in the eastern part of Algonquin Park, Theberge *et al.* (2006) estimated an average Eastern Wolf adult mortality rate of 0.30 between 1989 - 1999, although there was high variability in the estimates (Patterson and Murray 2008). Pimlott *et al.* (1969) noted high mortality in Eastern Wolves during the first year of life. Theberge and Theberge (2004) noted that yearlings and subadults were more susceptible than adults to human-caused mortality. Pup survival is estimated at 81% up to about 37 weeks of age with no observable mortality in the first 11 weeks (Mills *et al.* 2008). Within Algonquin Park, natural causes account for the majority of deaths (conspecific strife, drowning, Black Bear [*Ursus americanus*] predation, injuries caused by ungulates) followed by human-causes (poisoning and shooting after movement/dispersal outside the protected area).

Canine parvovirus (CPV-2) and canine distemper (CD) are not associated with pup deaths although exposure is evident (Mills *et al.* 2008). Pup mortality seems to vary among packs, for unknown reasons. Benson *et al.* (2013b) documented a total mortality rate in Algonquin Park of 44.3%, with natural causes accounting for 33.9% of deaths, 4.6% caused by human factors, and 5.8% unknown causes; pup mortality risk is associated with Beaver density and Deer availability. Outside Algonquin Park, high adult mortality is linked to Eastern Wolf ancestry (Benson *et al.* 2014) and poor pup survival is linked to Eastern Wolf x Eastern Coyote admixed ancestry (Benson *et al.* 2013b), making dispersal and expansion difficult for Eastern Wolves.

Theberge *et al.* (1994) reported that 6 of 18 radio-collared wolves died of rabies during an outbreak in 1990 - 91. Rabies has not been recorded in the population since then (Patterson 2011a, pers. comm.). Although human-caused mortality accounted for approximately 67% of wolf deaths in the eastern part of the Park prior to 2001, a ban on hunting and trapping in the three townships at the south end of the Park and surrounding townships, was implemented in December 2001 and has been successful in reducing human-caused mortality to 16% of all deaths (Rutledge *et al.* 2010e). The number of natural deaths, however, increased and generally offset those from human causes. Inter-pack strife is currently the main natural cause of death for adult Eastern Wolves in eastern Algonquin Park (Rutledge *et al.* 2010e) and starvation is a significant mortality risk for pups in the western part of the Park (Benson *et al.* 2013b).

In 2002/2003, directly after the implementation of the hunting and trapping ban in townships surrounding Algonquin Park, Eastern Wolf survival in the Park was 95.2% (±0.03 SE), but levelled off between 2003 - 2006 with survival rates between 81.6% and 84.2% (Patterson, unpub. data). Survival decreased significantly in 2006/2007 to 69.7% (±0.06 SE) when mange (caused by *Sarcoptes scabiei*) killed a large number of Eastern Wolves in the Park (see **Fluctuations and Trends**). Mange was rare and not debilitating for wolves in Algonquin Park from 1987 - 1999 (Theberge and Theberge 2004) suggesting that mortality (and thus population size) can fluctuate significantly from year to year due to unexpected events such as disease outbreaks.

Wolf hunting and trapping in Québec is prohibited in national and provincial parks but occurs elsewhere, including in wildlife reserves (St-Louis pers. comm. 2012). Human-caused mortality from trapping, vehicles, and hunting removed about 25-30% of a tagged population in the 1980s – 1990s (Jolicoeur and Hénault 2010). Harvest rates in Québec range regionally from 2.8 to 29.5%, with a provincial average of 5.9%. Villemure and Festa-Bianchet (2002) documented mortality of 53.3% in radio-collared wolves from La Mauricie Park, mostly due to trapping outside Park boundaries, which accounted for 87.5% of all mortalities, with pups most affected. A study conducted in Papineau-Labelle Reserve in the early 1980s documented a 34% mortality rate, with hunting and trapping accounting for 66% and roadkill 33% of the 33 *Canis* dying (Potvin 1988). Overall harvest rate in the Papineau-Labelle region was 9.0 – 17.3% in the late 1990s (Hénault and Jolicoeur 2003).

Eastern Wolves also suffered some mortality as a result of capture associated with research activities in Ontario. Between 2002 - 2011, 8 of 328 (2.4%) captured wolves died from capture-related mortality caught in traps, live-snares, or by heli-net-gunning (Patterson 2011c, pers. comm.). Two pups drowned post-capture because they had been relocated to a den site that later flooded; a third pup died 8 days post-capture of unknown causes (Argue *et al.* 2008).

Physiology and Adaptability

Gray Wolves are typically defined as highly adaptable to climatic variations given that they historically occurred from Mexico to the Arctic. There is considerably less information available on Eastern Wolves but it is likely that they have similar adaptability as other large *Canis* species.

Individual wolves can become acclimated when fed by people and when scavenging at landfill sites, and young dispersers sometimes frequent landfills (Mills *et al.* 2008).

Dispersal and Migration

Some adult Eastern Wolves in Algonquin Park migrated up to 42 km annually between their non-winter territory boundary and Deer concentration areas in response to Deer leaving the area during winter (Forbes and Theberge 1995; Forbes and Theberge 1996b; Loveless 2010; Rutledge *et al.* 2010e).

Annual dispersal probabilities were 0.22 (95% CI=0.108 – 0.318), 0.508 (0.341 – 0.633), and 0.144 (0.099 – 0.187) for pup, yearling, and adult *Canis* in Algonquin Park, respectively (B. Patterson unpub. data). Although dispersers often die or sometimes wander indefinitely, they typically form new packs or join existing packs as early as December. Once rendezvous sites are abandoned, juveniles start hunting and moving along with the pack.

Eastern Wolves have dispersed up to 555 km, and can cross mixed landscapes of forest, farmland, and 4-lane highways (Wydeven *et al.* 1998). Wolves from Algonquin Park dispersed south into the Kawartha Highlands Park, west toward Georgian Bay, and east into Québec. Radio-tagged juvenile Eastern Wolves typically did not disperse north, although one disperser from Algonquin Park was located in Nakina, northwestern Ontario, a direct distance of approximately 800 km (Patterson pers. comm.).

The main impediment to successful dispersal is high human-caused mortality, primarily hunting and trapping, outside protected areas (Forbes and Theberge 1996a; Wydeven *et al*. 1998; Benson *et al.* 2013b, 2014). In Ontario, when human-caused mortality was high, hybridization with Eastern Coyote increased (Rutledge *et al*. 2011) probably in response to a lack of conspecifc mates (Rutledge *et al*. 2010c) and disruption of pack social structure (Rutledge *et al*. 2010e). Expansion into historical range is also limited by lack of sufficiently connected forested areas containing low road and human densities (Harrison and Chapin 1998). Expansion northward appears to be limited, possibly due to the presence of the larger Great Lakes-Boreal Wolf and/or ecological requirements.

Interspecific Interactions

In Papineau-Labelle Reserve, *Canis* (of which some proportion likely were Eastern Wolf) mainly consumed Deer during winter, and Beaver and Moose during summer (Potvin *et al*. 1988). Beaver populations increased by 30% after 60% of *Canis* were removed (Potvin *et al*. 1992b). Similarly, Forbes and Theberge (1996b) found a high correlation between Eastern Wolf density and Deer numbers in winter. Prey selection by Eastern Wolves varies across months, seasons, and years (Forbes and Theberge 1996b; Loveless 2010). For example, in the eastern part of Algonquin Park, Theberge and Theberge (2004) noted that use of Beaver decreased from May to June and that consumption of adult Deer was highest in July. In some years, Moose were consumed more than Deer, although a high proportion was likely from scavenging. Eastern Wolves were documented as mostly scavengers of Moose in the 1980s (Forbes and Theberge 1992). More recent work suggests that they are an effective Moose predator; in 2006, Loveless (2010) noted that the proportion of Moose in the diet of Eastern Wolves was higher (64%) than in the preceding year (47%), and that overall biomass consumption increased from fall through mid-winter and decreased in late winter. Most Moose carcasses fed on were adults and the overall proportion of Moose vs. Deer in the diet tended to increase throughout the winter. Most Moose were depredated by packs that appeared to specialize on Moose. In the winter, pack size was correlated with Moose predation. Higher kill rates on Deer occurred in the fall, presumably in response to the fall migration of Deer. Older moose (>11 yrs) and calves were taken in higher proportion than their presence in the overall population.

The only known predator of adult Eastern Wolves are humans, but Black Bear occasionally prey on wolf pups (Mills *et al.* 2008). There have been no documented human deaths as a result of Eastern Wolf-human interactions, although injuries to people have occurred in Algonquin Park, likely as a result of wolves being fed within the campgrounds (Linnell *et al.* 2002).

Interactions with Eastern Coyote are discussed in the **Threats** section. Diseases are discussed in the **Threats** section because most diseases associated with Eastern Wolves are related to invasive disease and domestic animals.

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Population size is derived from density estimates, nuclear genetic assignment scores (*i.e.,* Q), and age class proportions of wolves in Algonquin Park. This method is then applied to areas where genetic analyses have established a location of Eastern Wolves (see **Global** and **Canadian Range**).

Abundance

The population size is unknown, but likely is < 1000 mature animals. Eastern Wolf are identified by genetic analyses of samples that have been collected in haphazard manner with different effort and during different time periods; an accurate population cannot be derived from such data. There have been 170 individuals identified in the common analysis for Ontario and Québec samples (Rutledge *et al*. 2010c, Benson *et al*. 2012; Rutledge and White 2013, 2014) and another 25 identified by Rogic *et al*. (2014), Henault (unpub. data), Tessier (unpub. data) within the extent of occurrence, for a total of 195 Eastern Wolf specimens from various sampling efforts over the last 10 - 15 years.

It is possible to roughly estimate abundance if we assume that the percentage of Eastern Wolf (Q≥0.8) and the proportion of mature animals sampled in one protected area (Algonquin Park), and the density of *Canis* in several sites is similar to other protected areas where Eastern Wolf have been recorded. It also is assumed that these metrics have remained constant over time. Over the past 3 generations (10.5 years), the number of wolves in Algonquin Park has remained at approximately 3/100 km^2 (Rutledge *et al.* 2010e), suggesting an extrapolated total of 227 wolves occurs within the Park boundaries (Table 2). Of the 128 *Canis* samples from Algonquin Park analyzed by Rutledge *et al.* (2010c), 88 (69%) had an assignment score of Q≥0.80. To estimate the number of mature individuals, (*i.e*., the number of individuals capable of reproducing), only those considered $\geq$2 years are included because that is the age at which first reproduction is known to occur (Pimlott *et al.* 1969). Therefore, the estimated number of mature Eastern Wolves in Algonquin Park (based on 45.9% of the population being adults) is 72 (Table 2). Extrapolating this approach to the other six Ontario sites results in an additional 82 animals, for a total of 154 mature Eastern Wolf in Ontario (Table 2).

Table 2. Abundance estimates of Eastern Wolves. Maximum # in Ontario (ON) sites is based on a density estimate of 3 wolves per 100 km^2 documented in Algonquin Park (Rutledge *et al.* 2010e), estimated # is based on 69% of the individuals with Q≥0.8 in STRUCTURE (Rutledge *et al.* 2010c), and # of mature individuals is based on 45.9% of the population being adults (Pimlott *et al.* 1969). Sites in Québec (QC) use a density of 2.6 wolves per 100 km^2 (Papineau-Labelle) or 1.9 per 100 km^2 (remaining sites). The closest abundance estimate of Eastern Wolf is 236 mature individuals.

Location	Area (km^2)	Maximum # of Eastern Wolves in these Sites	Estimated # of Eastern Wolves (Q≥0.8)	Estimated # Mature Individuals
Algonquin Park, ON	7,571	227	157	72
Algonquin Townships, ON	6,340	190	131	60
Kawartha Highlands Park, ON	376	11	8	4
Killarney Park, ON	645	19	13	6
Burwash/Bird Lake Area, ON	360	11	7	3
French River Park, ON	735	22	15	7
Queen Elizabeth II Park, ON	255	8	5	2
Papineau-Labelle Reserve, QC	1,628	42	29	13
Rouge-Matawin/Mont Tremblant, QC	3,165	60	41	19
La Mauricie Park, QC	536	10	7	3
Laurentide Reserve, QC	7,861	149	103	47
Total	29,472	749	516	236
Total (Extent of Occurrence)[a]	126,573	3797	2620	1203

[a] Estimate assumes that 69% of *Canis* outside the protected areas in the extent of occurrence (Figure 4) are Q≥0.8.

In Québec, *Canis* densities are available for two sites containing Eastern Wolf; Papineau-Labelle Reserve has an estimated 2.6 Wolves/100 km^2 and Rouge-Matawin Reserve has 1.6 - 1.9 Wolves/100 km^2 (Jolicoeur and Hénault 2010). It is assumed that Mont Tremblant Park, which is adjacent to Rouge-Matawin Reserve (Figure 6), has the same *Canis* density as Rouge-Matawin Reserve, as do the La Maurice and Laurentide sites, which are to the east. The Québec population size is estimated to be 82 mature animals.

The population of “Algonquin ecotype” wolves in Québec had been roughly estimated at 585 Wolves, based on a deciduous forest habitat and distribution of Deer (Jolicoeur and Henault 2002). The genetic analysis of Québec *Canis*, however, suggests few of these animals likely are Eastern Wolf with Q ≥0.8 (Rutledge and White 2014; Figure 4).

There is a small number of Eastern Wolf records located outside protected areas but within the extent of occurrence. These records typically are of single animals (Figure 3). A maximum population estimate is derived with an assumption that the density of Eastern Wolf outside the protected areas was the same as in Algonquin Park. The maximum population estimate would be 1203 mature animals in 126,573 km^2 for Canada. However, the assumption is inconsistent with observed patterns of admixture and the number is considered an over-estimation (*i.e*., a “best case scenario”) for the adult population.

In the previous COSEWIC status assessment (Samson 2001), the number of adult and juvenile Eastern Wolves in Canada was estimated at 1,311 – 2,684 over 210,000 km^2. The current minimum estimate of Eastern Wolves is 344 (including individuals of all ages) and the maximum is 1203 over a total extent of occurrence of 126,573 km^2 (Table 2). Lower numbers between COSEWIC reports reflect a reassessment of the extent of occurrence and changes to how Eastern Wolves are identified, rather than a measurable/comparable change in population size and range.

Fluctuations and Trends

The large *Canis* species was extirpated from the Maritimes, eastern United States, and southern parts of Ontario and Québec. If the Eastern Wolf inhabited this entire region (Figure 3b), or a more northerly part only (Figure 3a), then the historical loss of the Eastern Wolf population has been at least 50% of its range.

Recent population trends in Québec are not known. In Ontario, research efforts since the late 1950s have documented several atypical mortality events that caused short-term declines. Killing of wolves for research in 1964 - 1965 (Pimlott *et al.* 1969) decreased wolf density in the 1,700 km^2 study area from 4.7 wolves per 100 km^2 (n=80) in 1964 (prior to the study) to 2.4 per 100 km^2 in 1972 - 1973 (n=41). Between 1988 - 1999, Theberge and Theberge (2004) recorded a trend of decreasing wolf abundance in the eastern part of Algonquin Park due to human-caused mortality. Wolf density averaged 2.37 wolves per 100 km^2 (±0.57 SD) with the lowest recorded density at 1.4 per 100 km^2 in 1999. Estimated abundance in the study area was highest in 1991 - 1992 at 93 adults, and lowest in 1998 - 1999 at 38, suggesting a decrease in adults from 43 to 17, a 60% decrease in the study area, and a 5.0 - 16.6% decrease in the overall population of mature individuals. Survival was high immediately after the hunting ban was implemented in December 2001 (s = 95.2%), which presumably accounted for an increase in density. Survival stabilized between 2003 - 2006 at 81.6 - 84.2%, and was 85% between 2007 and 2010 (Benson *et al*. 2014). In 2006/2007, the population decreased significantly ($p < 0.05$) to 69.7% due to a mange outbreak (Patterson 2011b, pers. comm.) but increased afterwards.

The population trend for the Canadian population over the last three generations (*i.e*., 2005 - 2015) is unknown.

A population viability analysis (PVA) by Vucetich and Paquet (2000) suggested that the population of Eastern Wolves in Algonquin Park was in decline between 1988 - 1999 and that annual mortality (33%) exceeded annual recruitment (21%). Subsequently, Theberge *et al.* (2006) suggested it would be difficult to identify a positive response in wolf abundance to the harvest ban within 30 months of its implementation due to high stochasticity. Patterson and Murray (2008) suggested these analyses were flawed and in their re-analysis they concluded that a response in abundance would be detectable and that the population of wolves was unlikely to decrease significantly within the next 20 years. In Algonquin Park, the low occurrence of incestuous mating since the implementation of the harvest ban suggests inbreeding is not currently an issue within the Park; levels of inbreeding outside the Park are unknown but are believed to be higher, based on genetic analyses (Rutledge *et al.* 2010e).

Rescue Effect

The Eastern Wolf, as presently described, is not present in the United States and thus rescue effect is not possible. Although Red Wolves in the southeastern United States and Eastern Wolves in Canada probably evolved from the same historical population, there are high levels of hybridization in the Red Wolf population, including genetic contributions from Coyote, Gray Wolf, and Dog (see Appendix A). This mixed genome, combined with the limited evolutionary potential due to a genetic bottleneck associated with a founder effect of the captive breeding program, make the Red Wolf population an unviable option for an Eastern Wolf rescue effect in Canada.

THREATS AND LIMITING FACTORS

The Threats Calculator results are summarized in Appendix C. The overall threat score was Very High to High, based mainly on the likely continuing threat of mortality, and its impact on population expansion outside protected areas.

Limiting Factors

Territorial behaviour by Eastern Coyote may limit the expansion of Eastern Wolf from protected areas. There is evidence from research conducted in and near Algonquin Park that both Eastern Coyote and Eastern Wolf packs are territorial (Benson and Patterson 2013a). Eastern Wolf individuals travelling by themselves are unlikely to establish in areas already containing a pack of Eastern Coyote. Within the extent of occurrence, most areas outside the cores areas of Eastern Wolf contain Eastern Coyote.

Indirect Threats

In general, wolves are capable of living in agricultural areas and low density residential and commercial areas (Musiani *et al*. 2010). Deer populations may be abundant enough in rural areas, and food could be supplemented by scavenging garbage. However, wolves generally are not tolerated by society and may be killed; wolves typically are more common in areas without human activity or in areas with a lower density of agricultural, residential, or commercial development. The Threats Calculator exercise considers proximate factors, and therefore direct threats, such as habitat loss due to the expansion of housing, are presented in the Urban and Residential Development category, while a mortality event, regardless of it occurring in residential or forest areas, is discussed in the Hunting and Trapping category.

High Threat

Biological Resource Use - Hunting and Trapping (IUCN 5.1)

Wolves are a regulated furbearer species in the range of Eastern Wolf (see **Legal Protection and Status**). Eastern Wolves are protected from harvest within their core range of Algonquin Park, surrounding townships, and some other protected areas (see legal Protection and Status). In the remainder of their range, Eastern Wolf is subject to harvest. The number harvested is unknown because the canids appear similar enough that they are combined in auction summary data. In the 2011/2012 season, 571 ‘wolf’ pelts from trappers in Québec were sold (MFFP, 2012c). In the Great Lakes - Ontario region, 98 “Timber Wolves” including ‘Arctic’ and ‘Eastern’ were offered in the auction and 5,545 ‘Coyote’ pelts, including those from western and eastern geographies (Fur Harvesters Auction Inc. 2011).

Although most of the known population exists in protected areas, it is likely that mortality from humans limits the population elsewhere, and restricts expansion. Prior to the implementation of a hunting ban around Algonquin Park, human-caused mortality accounted for approximately 67% of wolf mortality in the eastern part of the park (Forbes and Theberge 1996a); post-ban (see **Legal Protection and Status**) it has decreased to 16% (Rutledge *et al.* 2010e). Outside the protected regions, hunting and trapping results in high mortality rates (Jolicoeur and Hénault 2010; Benson *et al*. 2014).

The degree to which pelt records indicate mortality rates is unknown. In Ontario, some people shoot wolves and Coyotes while hunting for Deer or Moose, in the belief that this increases ungulate populations (Patterson 2012b, pers. comm.). The extent of mortality from this behaviour is unknown in Eastern Wolf range.

Road density has been identified as a primary limiting factor to Eastern Wolf dispersal because roads are a proxy for increased hunting and trapping harvest. Hybridization with Eastern Coyotes is higher in regions of high road density (Benson *et al.* 2012), likely because high mortality rates associated with harvest access appear to facilitate Coyote introgression (see Taxonomic Validity and **Habitat Trends**). High road density in southern Ontario and Québec (Figure 6) likely would be a potential for roadkill and may severely impede natural expansion of Eastern Wolves into their historical range. Between 1985 and 1995 the number of single and multi-lane paved roads in southern Ontario increased by 3,025 km (Fenech *et al.* 2000), an average increase of 302.5 km per year, and suggestive that road density will continue to increase outside protected areas.

The presence of agricultural areas may mean increased Deer availability but these sites may be problematic for Eastern Wolf because of mortality by people in response to depredation of livestock in potential expansion areas. This threat is difficult to quantify because of the high variability in response from farmers (e.g. Stronen *et al.* 2007) and the divisive attitudes towards wolf management in agricultural areas where livestock predation occurs (Mech 2010b; Way and Bruskotter 2012).

Although positive attitudes towards wolves have increased over the past century (and in particular since the 1970s), attitudes can still be characterized as hostile in certain regions (Bruskotter *et al.* 2007, 2011; Williams *et al.* 2002). In the 1980s and 1990s, attitudes towards wolves in communities near Algonquin Park were generally unfavourable (Theberge and Theberge 2004). In Québec, the attitudes of trappers to wolves is variable, with about 42% opposing management to increase wolf numbers and the remainder either supporting the increase (29%), or undecided (29%), especially as it pertains to La Mauricie Park and surrounding regions (Bath 2006). A survey of residents near La Mauricie Park suggests most are sympathetic to the cause of the Eastern Wolf but most overestimated the number of wolves in the region and therefore were not necessarily supportive of management that aimed at increasing the population size (Parcs Canada 2007). The results of the survey suggest that better education of the public regarding wolves is an important component of wolf conservation in Québec. Societal shifts in values have been proposed as the most important factor in sustaining wolf populations worldwide (Musiani and Paquet 2004).

Medium Threats

Roads (IUCN 4.1)

The impact of vehicular collisions on the population of Eastern Wolf is unknown. Roads with high traffic volume exist throughout the extent of occurrence but are much less common in the protected sites. It is unlikely that there will be a large increase in new high volume roads, but traffic volume will likely increase on existing roads. A third of radio-collared *Canis* in Papineau-Labelle Reserve died from vehicles (Potvin 1988), and 2.7 ± 1% (SE) of adults, and 3.7 ± 2% (SE) of pups died in a sample of radio-collared Eastern Wolf in the Algonquin Park area from 2002 - 2007 (B. Patterson, unpub. data). From 2004 – 2010, 4.9% of Eastern Wolf were killed by vehicular collision in the same study area (Benson *et al*. 2014). The indirect threat of roads is discussed under biological resource use (IUCN 5.1).

Introduced Genetic Material (IUCN 8.3)

Coyotes were first documented in Ontario in Lambton County in 1919 (Nowak 1979). Since that time, they have hybridized with Eastern Wolves, resulting in a thriving population of Eastern Coyotes that are common across southern Ontario and from the eastern United States to Newfoundland (Way *et al.* 2010). The adaptability of these animals to human-modified landscapes has resulted in rapid colonization of areas in eastern North America (Kays *et al.* 2010) historically occupied by Eastern Wolves. High human-caused mortality is probably the primary cause of current hybridization of Eastern Wolves with Eastern Coyotes, except in Algonquin Park, where protection has curtailed ongoing hybridization (Rutledge *et al.* 2011). Outside the protected regions, however, almost all *Canis* are identified either as smaller Eastern Coyotes or highly admixed individuals (Eastern Wolf x Eastern Coyote hybrids). Very few are identified as Eastern Wolves despite absence of physical/geographic barriers. Thus, outside protected areas, gene introgression by Eastern Coyotes threatens the persistence of Eastern Wolves due to initial hybridization between the two species and then back-crossing to Eastern Coyotes (see **Habitat Requirements** and **Habitat Trends**).

Low Threats

Residential and Commercial Development (IUCN 1)

An increase in modified habitat, including land clearing for housing, can represent a decrease in habitat quality if prey species are not present. An area with high housing density will generally not contain prey for Eastern Wolf. However, much of Eastern Wolf range is composed of rural farms, cottages, and small towns, and Deer would occur in the rural areas. The main threat likely relates to increased contact between people and wolves, which could lead to higher wolf mortality; this indirect threat is discussed under biological resource use (IUCN 5.1). Urbanization and ongoing land conversion will continue to indirectly threaten Eastern Wolves' potential expansion. Residential and commercial development presently is a minor threat to Eastern Wolf because most of the population is located in protected areas that limit development (Figure 4). The projected rate of development of residential and commercial activity outside protected areas is unknown, but it is not likely to decrease.

Negligible Threats

Agriculture (IUCN 2)

An increase in modified habitat, including land clearing for agriculture, can be a direct problem for Eastern Wolf if prey species are not present. Although prey base in areas of Eastern Wolf range is unknown, Deer often are present in agricultural areas and agriculture is decreasing in some areas and reverting to forest (see Habitat Trends section).

Recreational Activities (IUCN 6.1)

Human intrusions, such as visitation to dens or rendezvous sites, could have an impact on Eastern Wolves because wolves tend to avoid humans and relocate pups after den disturbance (Frame *et al*. 2007). The effect likely would be limited because the core of the population occurs in protected areas where human activities are regulated. The extent of disturbance is unknown, but likely is negligible.

Unknown (Unquantified) Threats

Invasive Non-native Species (IUCN 8.1)

Domestic dogs have exposed Eastern Wolves to domestic diseases, including canine parvovirus-2 (CPV-2), canine distemper (CD), and canine hepatitis (CH). Antibodies for these diseases are found in most Eastern Wolf pups at an early age, but exposure does not typically result in death (Theberge and Theberge 2004; Mills *et al.* 2008). Theberge and Theberge (2004) noted antibodies in Eastern Wolves for CPV (82%), CH (76%) CD (46%), and rabies (20%). Although domestic disease-related deaths have been rare in wolves from Algonquin Park, the Isle Royale National Park, Minnesota, wolf population suffered a dramatic decline in numbers between 1980 - 1982 due to a CPV outbreak that left the population with only 14 wolves (Peterson *et al.* 1998). Disease can be an important extinction risk in small relict wild canid populations (Woodroffe *et al.* 2004).

The threat exists because there is a potential for mortality from domestic dogs associated with tourism in protected areas, and a decrease in adult animals could increase levels of Coyote gene introgression in Eastern Wolf (see Taxonomic Validity). The threat level is considered to be low because a level of immunity to parvovirus appears to exist in the population.

Rabies in wolves and coyotes is rare, although 15 cases were documented in Ontario between 1960 - 1994 (Theberge *et al.* 1994). During winter of 1990 – 1991, 4 wolves (perhaps 6) died of rabies (Theberge *et al.* 1994), but no rabies-related deaths have since been documented (Patterson 2011, pers. comm.). The rabies outbreak in Algonquin Park wolves was thought to be linked to an outbreak of fox strain rabies during 1990 – 1991 (Theberge and Theberge 2004). The survival of those Eastern Wolves that had antibodies for rabies is thought to be due to ingestion of oral rabies vaccine bait that was distributed in eastern Algonquin Park in 1991 – 1992.

Habitat Shifting and Alteration (IUCN 11.1)

There currently are no direct estimates of how climate change could affect Eastern Wolves. However, effects of climate change on Moose populations predict a decline in Moose density in the southern limits (south of Hwy 101; ≈48th parallel) of Ontario, particularly in the region of Algonquin Park (Rempel 2011). In general, models predict a northward movement of Moose with populations in the southern regions receding due to marginal climate and habitat (Murray *et al.* 2006) and expansion of parasitic disease associated with increased Deer density (Lankester 2010). Although Murray *et al.* (2006) suggested that climate change should benefit Deer populations, they also noted that it is difficult to predict how warmer temperatures will impact deer parasites. In general, Deer density is expected to increase across Ontario and Québec (Thompson *et al.* 1998), which could benefit Eastern Wolves. Lankester (2010) also suggested winters will get shorter and milder with longer snow-free periods, which will reduce the hunting success of Eastern Wolves since they have an advantage compared to ungulates in deep snow conditions (DelGiudice *et al.* 2002; Crête and Larivière 2003).

Most studies on climate change have focused on plant-herbivore actions and there are relatively few studies that examine the impact of climate change on high-level trophic interactions. Wilmers *et al.* (2007) demonstrated that in the absence of wolves, Moose populations are predicted to be more susceptible to climatic variations. Wilmers *et al.* (2006) provided evidence that wolves mediate the impact of climate change on ungulate populations. Thus a healthy Eastern Wolf population may be important for mediating fluctuating ungulate populations predicted in response to climate change. The direct and indirect effects of climate change on the Eastern Wolf population are unknown.

PROTECTION, STATUS, AND RANKS

Legal Protection and Status

The Eastern Wolf is listed as Special Concern on Schedule 1 of the federal *Species at Risk Act* (*SARA*), under the scientific name *Canis lupus lycaon*. An Eastern Wolf Management Plan, required under *SARA* for special concern species, is under development by Environment Canada.

Gray Wolves are listed under Appendix II of the Convention on International Trade in Endangered Species (CITES), which is administered in Canada by Environment Canada. CITES permits are required to export wolves from Canada, including Eastern Wolf specimens (recognized as *Canis lupus lycaon*). Other than CITES, there are currently no international agreements for protection that would include Eastern Wolf.

<u>Ontario</u>

The Eastern Wolf is considered to be a subspecies of *Canis lupus.*

The Eastern Wolf is listed under Ontario's *Endangered Species Act,* 2007 (Ontario Government 2007) as a Gray Wolf subspecies (*C. lupus lycaon*) with a status of Special Concern. The NatureServe S-rank is S4 for Ontario.

Under the *Fish and Wildlife Conservation Act, 1997* (Ontario Government 1997), all animals of the species *Canis lupus* are considered furbearing mammals, and are provided protection. Hunting and trapping of wolves are regulated under regulations of the *Fish and Wildlife Conservation Act, 1997*, and harvest is controlled and monitored. In addition to a small game licence, a wolf/coyote game seal (maximum of 2 per year) is required to hunt wolves in core wolf range (Wildlife Management Units 1A, 1C, 1D, 2-42, 46-50 and 53-58). Wolves can also be hunted or trapped under a trapping licence. The Act provides authority to limit harvest by trappers if necessary.

Where regulated hunting and trapping are permitted, the wolf and Coyote season is closed from April 1 to September 14 across core wolf range identified above. Wolves (along with Coyotes) can be hunted and trapped year round south of core wolf range, and there are no limits on harvest. However, this area is considered outside the current extent of occurrence of Eastern Wolves, but within their historical range.

There is no open hunting/trapping season for wolves in 40 townships around Algonquin Park: Airy, Alice, Ballantyne, Boulter, Boyd, Burns, Butt, Calvin, Cameron, Chisholm, Clancy, Clara, Dickens, Dudley, Eyre, Finlayson, Franklin, Fraser, Hagarty, Harburn, Harcourt, Havelock, Head, Herschel, Lauder, Livingstone, Maria, McClintock, McClure, McCraney, McKay, Murchison, Papineau, Paxton, Petawawa, Richards, Rolph, Sabine, Sinclair, and Wylie.

Wolves may not be hunted or trapped in the following protected areas: Pukaskwa Park, Algonquin Park, and all Crown Game Preserves. They are protected from regulated hunting in all other Provincial Parks (except Point Farms Provincial Park in southern Ontario, which is presumed to be outside core wolf range), and are protected from trapping in over half of the Provincial Parks. Wolves can be trapped in Kawartha Highlands and French River Park. Trapping will be eliminated from one-third of the remaining parks where it currently occurs under a phase out policy.

Mandatory reporting of activity and harvests is required by hunters and trappers. A person who kills a wolf in protection of property must either register the acquisition of the carcass online, if keeping the carcass, by submitting a Notice of Possession, or report the killing immediately to the Ministry if not keeping the carcass.

Residents and non-residents must have an Ontario export licence for furbearing mammals and their pelts to export a wolf or Coyote, as well as its pelt, from Ontario whether it originated from Ontario or not, and including carcasses and live wolves and coyotes. Royalties are payable on Ontario wolves and Coyotes prior to their export from Ontario.

The Strategy for Wolf Conservation in Ontario (OMNR 2005) provides the strategic policy direction for the management of wolves in Ontario.

Den and rendezvous sites for Eastern Wolf on Crown Land are protected as part of provincial forest management guidelines (OMNR 2010).

Québec

In Québec, wolves are considered a furbearer and are protected under An Act Respecting the Conservation and Development of Wildlife but not under *Loi sur les espèces menacées ou vulnérables* [Act respecting Threatened or Vulnerable Species in Québec]. The Eastern Wolf is not officially recognized because the province does not recognize wolf subspecies (MFFP 2011); the Act only acknowledges taxonomic nomenclature as outlined by the Smithsonian Museum of Natural History and the Integrated Taxonomic Information System (www.itis.gov) (MFFP 2012a). Currently, wolf hunting and trapping is prohibited in all federal and national (provincial) parks but permitted elsewhere, including wildlife reserves (St. Louis pers. comm.). In most areas, the harvest season is late October – late March, and there is no bag limit.

Non-Legal Status and Ranks

NatureServe (http://www.natureserve.org/explorer/) lists the Eastern Wolf as a subspecies of Gray Wolf (*Canis lupus lycaon*) and ranks it as G4G5TNR (apparently secure/secure) and N4 nationally. At the provincial scale, Québec has not assessed the Eastern Wolf, and Ontario has assigned a rank of S4 – apparently secure.

Habitat Protection and Ownership

Mortality from human activity is the most important feature of habitat for Eastern Wolves. Within the current occupied areas in Ontario, the total habitat without harvest of Eastern Wolf includes Algonquin Park (7,571 km^2) and surrounding townships (6,340 km^2), Queen Elizabeth II Wildlands (255 km^2), and Killarney Park (645 km^2), for a total of 14,811 km^2. Wolf harvest is permitted in Kawartha Highlands Park (376 km^2) and French River Park (735 km^2), but they would represent areas where human activity (e.g., buildings, roads, etc.) would be relatively limited.

In Québec, there are wildlife reserves and Zecs (zones d'expoitation contrôlées [controlled exploitation zones]) (e.g. Papineau-Labelle [1628 km^2], Rouge-Matawin, Mastigouche, Saint Maurice, Port-Neuf, and Laurentides) that would contain less development than elsewhere and likely more prey, but these reserves generally are oriented towards extractive activities such as hunting and trapping. As such, their role as sites that would minimize Eastern Coyote gene introgression is uncertain. Harvest of Canids is not permitted in Mont Tremblant (1510 km^2) and La Mauricie (536 km^2) Parks.

ACKNOWLEDGEMENTS AND AUTHORITIES CONTACTED

Thank you to Jenny Wu at Environment Canada for creating the map figures for this report and to Dr. Graham Forbes for overseeing and providing editorial comments on the draft versions. Also, thank you to the following people and agencies that were contacted for information, input, and/or feedback for the status report.

Maria de Almeida, Wildlife Policy Section, Ontario Ministry of Natural Resources and Forestry, Peterborough ON.

Jeff Bowman. Ontario Ministry Natural Resources and Forestry, Peterborough, ON.

Robert Craig, Natural Heritage Information Centre Information Analyst, Ontario Ministry of Natural Resources, ON.

Marie-France Dalcourt, Acting Manager Population Conservation Section, Canadian Wildlife Service – Québec Region.

Dave Duncan, Regional Director, Canadian Wildlife Service, Prairie and Northern Regions, Environment Canada, MB.

Isabelle Gauthier, Ministère des Forêts, de la Faune et des Parcs (MFFP) du Québec, Biologiste. Coordonnatrice provinciale, espèces fauniques menacées et vulnérables, QC.

Hélène Jolicoeur, Retired from Ministère des Ressources Naturelles et de la Faune (MFFP) du Québec.

Christopher Kyle, Assistant Professor, Trent University, Peterborough, ON.

Michel Henault, Ministère des Forêts, de la Faune et des Parcs, Direction de la gestion de la faune de Lanaudière et des Laurentides.

Briar Howes, Critical Habitat Biologist, Species at Risk, Parks Canada.

Hank Hristienko, Manitoba Conservation Wildlife and Ecosystem Protection Branch, MB.

Henry Lickers, Director of Environment, Mohawk Council of Akwesasne, Ontario/Quebec.

Angela McConnell, Canadian Wildlife Service, Ottawa, ON.

Patrick Nantel, Parks Canada, Conservation Biologist, Species at Risk Program, QC.

Dean Nernberg, Species at Risk Officer, National Defence.

Ronald Nowak, retired US Fish and Wildlife Service.

Michael Oldham, Natural Heritage Information Centre, Ontario Ministry of Natural Resources, ON.

Sylvain Paradis, Coordinator, Species at Risk, Parks Canada, QC.

Brent Patterson, Wildlife Research and Development Section, Ontario Ministry of Natural Resources and Forestry, ON.

Annie Paquet, Centre de données sur le patrimoine naturel du Québec. Ministère des Forêts, de la Faune et des Parcs (MFFP) du Québec. Direction de l'expertise sur la faune et ses habitats.

Jason Pitre, ATK Coordinator, COSEWIC Secretariat, Canadian Wildlife Service.

Chris Risley, Bird and Mammal Species at Risk Specialist, Species at Risk Branch, Ontario Ministry of Natural Resources, ON.

Brad Steinberg, Management Biologist, Algonquin Park, ON.

Antoine St.-Louis, Ministère des Forêts, de la Faune et des Parcs (MFFP) du Québec, Biologiste des espèces menacées.

Astrid vik Stronen, BIOCONSUS Fellow, Mammal Research Institute, Poland

Rick Stronks, Chief Park Naturalist, Algonquin Park, ON.

Richard Thiel, Retired Wildlife Biologist, Wisconsin Department of Natural Resources.

Mario Villemure, Resource Conservation Technician, La Mauricie National Park, QC.

Bradley White, Chair of Biology, Trent University, Peterborough, ON.

Paul Wilson, Canada Research Chair in DNA Profiling, Trent University, Peterborough, ON.

Adrian Wydeven, Mammalian Ecologist/Conservation Biologist, Wisconsin Department of Natural Resources.

INFORMATION SOURCES

Argue, A.M., Mills, K.J., and B.R. Patterson. 2008. Behavioural response of eastern wolves (*Canis lycaon*) to disturbance at homesites and its effects on pup survival. Canadian Journal of Zoology 86: 400-406.

Bath, A.J. 2006. Human dimensions in wolf conservation: understanding trapper's perceptions toward wolves in and around La Mauricie National Park of Canada, Rapport présenté au Centre de services de Parcs Canada au Québec, 96 pp.

Benson, J.F., Patterson, B.R., and T.J. Wheeldon. 2012. Spatial genetic and morphologic structure of wolves and coyotes in relation to environmental heterogeneity in a *Canis* hybrid zone. Molecular Ecology 21: 5934-5954.

Benson, J.F. and B. R. Patterson. 2013a. Inter-specific territoriality in a *Canis* hybrid zone: spatial segregation between wolves, coyotes, and hybrids. Oecologia. 173: 1539-1550.

Benson, J. F., Mills, K.J., Loveless, K.M., and B.R. Patterson. 2013b. Genetic and environmental influences on pup mortality risk for wolves and coyotes within a *Canis* hybrid zone. Biological Conservation. 166: 133-141.

Benson, J.F., Patterson, B.R., and P.J. Mahoney. 2014. A protected area influences genotype-specific survival and the structure of a *Canis* hybrid zone. Ecology 95: 254-264.

Bertorelle, G., and L. Excoffier 1998. Inferring admixture proportions from molecular data. Molecular Biology and Evolution 15:1298-1311.

Beschta, R.L., and W.J. Ripple. 2009. Large predators and trophic cascades in terrestrial ecosystems of the western United States. Biological Conservation. 142: 2401-2414.

Beschta, R.L., and W.J. Ripple. 2010. Recovering riparian plant communities with wolves in northern Yellowstone, USA. Restoration Ecology 18: 380-389.

Brainerd, S.M., (and 6 co-authors). 2008. The effects of breeder loss on wolves. Journal of Wildlife Management 72: 89-98.

Bruskotter, J.T., Schmidt, R.H., and T.L. Teel. 2007. Are attitudes toward wolves changing? A case study in Utah. Biological Conservation 139: 211-218.

Bruskotter, J.T., Toman, E., Enzler, S.A., and R.H. Schmidt. 2011. Gray wolves not out of the woods yet. Science 327: 30-31.

Buss, M., and M. deAlmeida. 1997. A review of wolf and coyote status and policy in Ontario. Ontario Ministry of Natural Resources. 88 pp.

Carbone, C., Mace, G.M., Roberts, S.C., and D.W. Macdonald. 1999. Energetic constraints on the diet of terrestrial carnivores. Nature 402: 286-288.

CEC (Commission for Environmental Cooperation) 1997. Ecological regions of North America: a common perspective. Montreal, QC.

Chambers, S., S. Fain, B. Fazio, and M. Amaral. 2012. An account of the taxonomy of North American wolves from morphological and genetic analyses. North American Fauna 77:1-67. USFWS. Doi:10.3996/nafa.77.0001.

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2014. Operations and Procedures Manual, April 2014. COSEWIC Secretariat. Website: http://www.cosewic.gc.ca/eng/sct2/sct2_8_e.cfm. [accessed February 2015].

Cronin, M.A, and L.D. Mech. 2009. Problems with the claim of ecotype and taxon status of the wolf in the Great Lakes region. Molecular Ecology 18: 4991-4993.

Chapron, G., Andren, H., and O. Liberg. 2008. Conserving top predators in ecosystems. Science. 320: 47.

Crête, M., and S. Larivière. 2003. Estimating the costs of locomotion in snow for coyotes. Canadian Journal of Zoology 81: 1808-1814.

DelGiudice, G.D., Riggs, M.R., Joly, P., and W. Pan. 2002. Winter severity, survival, and cause-specific mortality of female white-tailed deer in north-central Minnesota. Journal of Wildlife Management. 66: 698-717.

Dowling, T., (and 4 co-authors). 1992. Response to Wayne, Nowak, and Phillips and Henry: Use of molecular characteristics in conservation biology. Conservation Biology 6:600-603.

Fain, S.R., Straughan, D.J., and B.F. Taylor. 2010. Genetic outcomes of wolf recovery in the western Great Lakes states. Conservation Genetics 11: 1747-1765.

Fenech, A., Taylor, B., Hansell, R., and G. Whitelaw. 2000. Major road changes in southern Ontario 1935-1995: Implications for protected areas. Integrated Mapping Assessment Project. University of Toronto. Website: http://www.utoronto.ca/imap/papers/road_changes.htm [accessed January 9, 2011]

Fogelqvist J., Niittyvuopio, A., Ågren J., Savolainen O., and M. Lascoux. 2010. Cryptic population genetic structure: the number of inferred clusters depends on samples size. Molecular Ecology Resources 10: 314-323.

Forbes, G.J., and J.B. Theberge. 1992. Importance of scavenging on moose by wolves in Algonquin Park, Ontario. Alces 28: 235-241.

Forbes, G.J., and J.B. Theberge. 1995. Influences of a migratory deer herd on wolf movements and mortality in and around Algonquin Park, Ontario. Pp. 303-314 *in* Ecology and Conservation of Wolves in a Changing World. L. Carbyn, S. Fritts, and D. Seip (eds). Canadian Circumpolar Institute, University of Alberta, Edmonton, Alberta. 619 pp.

Forbes, G.J., and J.B. Theberge. 1996a. Cross-boundary management of Algonquin Park wolves. Conservation Biology 10: 1091-1097.

Forbes, G.J., and J.B. Theberge. 1996b. Response of wolves to prey variation in central Ontario. Canadian Journal of Zoology 74: 1511-1520.

Frame. P., D. Cluff and D. Hik. 2007. Response of wolves to experimental disturbance at homesites. Journal of Wildlife Management 71:313-320.

Fryxell, J.M. 2001. Habitat suitability and source-sink dynamics of beavers. Journal of Animal Ecology 70: 310-316.

Fuller, T.K., Mech, D.L., and J.F. Cochrane. 2003. Wolf population dynamics. Pp. 161-191 *in* Wolves: Behavior, Ecology, and Conservation. D.L. Mech and L. Boitani (eds). University of Chicago Press, Chicago.

Fur Harvesters Auction Inc. 2011. Sale Results for January 7, 2011. http://www.furharvesters.com/results/2011/jan11cdnbi.pdf.

Garcia-Moreno J., M. Matocq, M. Roy, E. Geffen E, and R. Wayne. 1996. Relationships and genetic purity of the endangered Mexican wolf based on analysis of microsatellite loci. Conservation Biology 10: 376–389.

Goldman, E. 1937. The wolves of North America. Journal of Mammalogy 18:37-45.

Grewal, S.K., Wilson, P.J., Kung, T.K., Shami, K., Theberge, M.T., Theberge, J.B., and B.N. White. 2004. A genetic assessment of the eastern wolf (*Canis lycaon*) in Algonquin Provincial Park. Journal of Mammalogy 85:625-632.

Hailer F., and J.A. Leonard. 2008. Hybridisation among three native North American *Canis* species in a region of natural sympatry. PLoS ONE 3(10): e3333. doi:10.1371/journal.pone.0003333.

Harrison, D.J., and T.G. Chapin 1998. Extent and connectivity of habitat for wolves in eastern North America. Wildlife Society Bulletin 26:767-775.

Hedrick P., P. Miller, E. Geffen, and R. Wayne. 1997. Genetic evaluation of three captive Mexican wolf lineages. Zoological Biology 16:47–69.

Hénault, M. Unpublished data. Information contained in Québec jurisdictional review of Eastern Wolf Report. February 2015.

Hénault, M., and H. Jolicouer. 2003. Les loups au Québec: Meutes et mystères. Société de la faune et des Parcs du Québec, Direction de l'aménagement de la région des Laurentides, Direction du développement de la faune, 129 p.

Hubisz, M.J., Falush, D., Stephens, M., Pritchard, J.K. 2009. Inferring weak population structure with the assistance of sample group information. Molecular Ecology Resources 9: 1322-1332.

Jolicoeur, H., and Hénault, M. 2002. Répartition géographique du loup et du coyote au sud du 52e parallèle et estimation de la population de loups au Québec. Société de la faune et des parcs du Québec. ISBN: 2-550-39485-2.

Jolicoeur, H., and M. Hénault. 2010. Current status and management of Wolves in Québec. Wolf Stewards Meeting, Dorset, Ontario.

Jost, L. 2008. Gst and its relatives do not measure differentiation. Molecular Ecology 17: 4015-4026.

Kays, R., Curtis, A., and J.J. Kirchman. 2010. Rapid adaptive evolution of northeastern coyotes via hybridisation with wolves. Biology Letters 6: 89-93.

Kennedy, L.J. 2012. pers. comm. *Email correspondence to L Rutledge* January 9, 2012. Senior Scientist, University of Manchester, Centre for Integrated Genomic Medical Research, Manchester, United Kingdom.

Koblmüller, S., Nord, M., Wayne, R.K., Leonard, J.A. 2009. Origin and status of the Great Lakes wolf. Molecular Ecology. 11: 2313-2326.

Kolenosky, G., and R. Standfield. 1975. Morphological and ecological variation among Gray wolves (*Canis* lupus) of Ontario, Canada. Pp 62-72. in M. Fox (ed.). The Wild Canids. Van Nostrand Reinhold: New York.

Kurten, B., and E. Anderson, 1980. Pleistocene mammals of North America. Columbia Press, NY.

Kyle, C.J., Johnson, A.R., Patterson, B.R., Wilson, P.J., Shami, K., Grewal, S.K., and B.N. White. 2006. Genetic nature of eastern wolves: past, present and future. Conservation Genetics 7: 273-287.

Kyle, C.J., Johnson, A.R., Patterson, B.R., Wilson, P.J., and B.N. White. 2008. The conspecific nature of eastern and red wolves: conservation and management implications. Conservation Genetics. 9: 699-701.

Lancaster, P.A., Bowman, J., and B.A. Pond. 2008. Fishers, farms, and forests in eastern North America. Environmental Management 42: 93-101.

Lankester, M.W. 2010. Understanding the impact of meningeal worm, *Parelaphostrongylus tenuis*, on moose populations. Alces 46: 53-70.

Lehman, N., (and 6 co-authors). 1991. Introgression of coyote mitochondrial DNA genotype frequencies: estimation of the effective number of alleles. Evolution 45: 104-119.

Leonard, J.A., and R.K. Wayne. 2005. Legacy lost: genetic variability and population size of extirpated US Gray wolves (*Canis lupus*). Molecular Ecology 14: 9-17.

Leonard, J.A., and R.K. Wayne. 2008. Native Great Lakes wolves were not restored. Biology Letters 4: 95-98.

Lesmarises, F., C. Dussault, and M-H. St-Laurent. 2012. Wolf habitat selection is shaped by human activities in a highly managed boreal forest. Forest Ecology and Management 276:125-131.

Lickers, H. Email correspondence with G. Goulet, TMSSC Member, COSEWIC. April 2015.

Linnell, J.D.C., Andersen, R., Andersone, Z. *et al.* 2002. The fear of wolves: A review of wolf attacks on humans. NINA Oppdragsmelding: 731: 1-65. http://www.lcie.org/docs/damage%20prevention/linnell%20nina%20op%20731%20fear%20of%20wolves%20eng.pdf

Lohr, C., and W.B. Ballard. 1996. Historical occurrence of wolves, *Canis lupus* in the Maritime Provinces. Canadian Field-Naturalist 110: 607-610.

Loveless, K. 2010. Foraging strategies of eastern wolves in relation to migratory prey and hybridisation. Masters thesis. Trent University, Peterborough, ON. 73 pp.

MacNulty, D.R., Smith, D.W., Mech, L.D., and L.E. Eberly. 2009. Body size and predatory performance in wolves: is bigger better? Journal of Animal Ecology 78: 532-539.

Manning, R., and W. Sturtevant 1966. Early specimens of the eastern wolf, *Canis lupus lycaon*. Chesapeake Science 7: 218-220.

McCarley, H., and J. Carley. 1979. Recent changes in distribution and status of red wolves (*Canis rufus*). Endangered Species Report no.4. U.S. Fish and Wildlife Service, Albuquerque, NM.

Mech, L.D., and L. Boitani. 2003. Wolf social ecology. Pp. 1-34. *in* D.L. Mech, and L. Boitani (eds.). Wolves: Behavior, Ecology and Conservation. University of Chicago Press, Chicago.

Mech, D., S. Fritts, and G. Radde. 1988. Wolf distribution and road density in Minnesota. Wildlife Society Bulletin 16:85-87.

Mech, L.D. 2010a. What is the taxonomic identity of Minnesota wolves? Canadian Journal of Zoology 88: 129-138.

Mech, L.D. 2010b. Considerations for developing wolf harvest regulations in the contiguous United States. Journal of Wildlife Management 74: 1421-1424.

Mech, L.D. 2011. Non-genetic data supporting genetic evidence for the eastern wolf. Northeastern Naturalist 18: 521-526.

Mech, L.D., (and 4 co-authors). 2014. Production of hybrids between western gray wolves and western coyotes. PloSONE 9(2):e88861.doi:10.1371.

MFFP (Ministère des Forêts, de la Faune et des Parcs). 2011.

Email correspondence to L Rutledge from Annie Paquet. May 13, 2011. Technicienne de la faune. Service de la biodiversité et des maladies de la faune, Québec.

MFFP (Ministère des Forêts, de la Faune et des Parcs). 2012a.

Comments on the COSEWIC status report for the eastern wolf (*Canis lycaon*). E-mail correspondence to Graham Forbes, July 26, 2012.

MFFP (Ministère des Forêts, de la Faune et des Parcs). 2012b. Web site:http://www.mrn.gouv.qc.ca/english/territory/portrait/index.jsp [accessed December 8, 2011].

MFFP (Ministère des Forêts, de la Faune et des Parcs). 2012c. Web site:http://www.MFFP.gouv.qc.ca/english/wildlife/statistics/index.jsp#trapping [accessed August 20, 2012].

Miller, G. 1912. The names of two North American wolves. Proceedings Biological Society of Washington. 25:93.

Mills, K.J. 2006. Wolf (*Canis lycaon*) pup survival, dispersal, and movements in Algonquin Provincial Park, Ontario. Masters thesis. Trent University, Peterborough, ON, 67 pp.

Mills, K.J., Patterson, B.R., and D.L. Murray. 2008. Direct estimation of early survival and movements in eastern wolf pups. Journal of Wildlife Management 72: 949-954.

Murray, D.L., and L.P. Waits. 2008. Taxonomic status and conservation strategy of the endangered red wolf: a response to Kyle et al. (2006). Conservation Genetics 8: 1483-1485.

Murray, D.L., (and 7 co-authors). 2006. Pathogens, nutritional deficiency, and climate influences on a declining moose population. Wildlife Monographs 166: 1-20.

Musiani, M., L. Boitani, and P. Paquet. 2010. The World of Wolves: New Perspectives on Ecology, Behaviour and Management. University of Calgary Press. 398 pp.

Musiani, M., and P.C. Paquet. 2004. The practices of wolf persecution, protection, and restoration in Canada and the United States. BioScience 54: 50-60.

Naughton, D. 2012. The Natural History of Canadian Mammals. University of Toronto Press, Toronto, ON. 784 pp.

NCEAS (National Center for Ecological Analysis and Synthesis). 2014. Review of the proposed rule regarding status of the wolf under the ESA. Santa Barbara, CA. 68 pp.

Norris, D.R., Theberge, M.T., and J.B. Theberge. 2002. Forest composition around wolf (*Canis lupus*) dens in eastern Algonquin Provincial Park, Ontario. Canadian Journal of Zoology 80: 866-872.

Nowak, R.M. 1979. North American Quaternary *Canis.* Museum of Natural History, University of Kansas (Monograph No. 6), Lawrence, Kansas.

Nowak, R.M. 1992. The red wolf is not a hybrid. Conservation Biology 6:593-595.

Nowak, R.M. 1995. Another look at wolf taxonomy. Pp. 375-398, *in* L.N. Carbyn, S.H. Fritts and D.R. Seip (eds.). Ecology and Conservation of Wolves in a Changing World. Canadian Circumpolar Institute, Occasional Publication No. 35, 642 pp.

Nowak, R.M. 2002. The original status of wolves in eastern North America. Southeastern Naturalist 1(2): 95-130.

Nowak, R.M. 2009. Taxonomy, morphology, and genetics of wolves in the Great Lakes region. *in* A.P. Wydeven, T.R. vanDeelen, and E. Heske (eds.), Recovery of Gray Wolves in the Great Lakes Region of the United States. Springer Publishing, 350 pp.

Nowak, R.M., pers. comm. 2011. *Email correspondence to L. Rutledge.* August, 2011. Wolf taxonomist, retired from US Fish and Wildlife Service.

OMNR (Ontario Ministry of Natural Resources). 2005. Strategy for Wolf Conservation in Ontario, Ontario Ministry of Natural Resources, report. http://www. ontario.ca/environment-and-energy/wolf-conservation-strategy. [accessed February, 2015].

OMNR (Ontario Ministry of Natural Resources). 2009. Cervid Ecological Framework. http://www.ontario.ca/environment-and-energy/cervid-ecological framework. [accessed February, 2015].

OMNR (Ontario Ministry of Natural Resources). 2010. Forest Management Guide for Conserving Biodiversity at the Stand and Site Scales. Queen’s Printer, Toronto, ON.

OMNR (Ontario Ministry of Natural Resources). 2012. Wildlife Management Unit Maps. http://www. ontario.ca/environment-and-energy/find-wildlife-management-unit-wmu-map. [accessed February, 2015].

Ontario Government, Fish and Wildlife Conservation Act, 1997, S.O. 1997, c. 41. http://www.e-laws.gov.on.ca/html/statutes/english/elaws_statutes_97f41_e.htm

Ontario Government, Endangered Species Act, 2007, S.O. 2007, c. 6, http://www.e-laws.gov.on.ca/html/statutes/english/elaws_statutes_07e06_e.htm

Parcs Canada. 2007. Étude sur les attitudes, perceptions et connaissances des résidents de la région limitrophe du parc national du Canada de la Mauricie à l’égard du loup de l’Est. Rapport final, Mars 2007. Numéro de contrat: 5P201-060514 – POR-273-06.

Parker, G. 1995. Eastern Coyote: The Story of its Success. Nimbus Publishing, Halifax, NS. 254 pp.

Patterson, B.R., 2011a, pers. comm. *Email correspondence to L Rutledge.* October 14, 2011. Research Scientist, Ontario Ministry of Natural Resources, Trent University, Peterborough, Ontario.

Patterson, B.R., 2011b, pers. comm. *Email correspondence to L Rutledge* November 21, 2011. Research Scientist, Ontario Ministry of Natural Resources, Trent University, Peterborough, Ontario.

Patterson, B.R., 2011c, pers. comm. *Email correspondence to L Rutledge* December 18, 2011*.* Research Scientist, Ontario Ministry of Natural Resources, Trent University, Peterborough, Ontario.

Patterson, B.R., 2012, pers. comm. *Email correspondence to L Rutledge in comment on draft.* January 12, 2012*.* Research Scientist, Ontario Ministry of Natural Resources, Trent University, Peterborough, Ontario.

Patterson, B.R., 2012b, pers. comm. *Email correspondence to L Rutledge.* February 1, 2012*.* Research Scientist, Ontario Ministry of Natural Resources, Trent University, Peterborough, Ontario.

Patterson, B.R., 2014, pers. comm. *Email correspondence to L Rutledge.* July 2, 2014*.* Research Scientist, Ontario Ministry of Natural Resources, Trent University, Peterborough, Ontario.

Patterson, B.R., and D.L. Murray. 2008. Flawed population viability analysis can result in misleading population assessment: a case study for wolves in Algonquin Park, Canada. Biological Conservation 141:669-680.

Person, D., and A. Russell. Correlates of wolf mortality in an exploited wolf population. Journal of Wildlife Management 72:1540-1549.

Peterson, R.O., Thomas, N.J., Thurber, J.M., Vucetich, J.A., and T.A. Waite. 1998. Population limitation and the wolves of Isle Royale. Journal of Mammalogy 79: 828-841.

Pilgrim KL, Boyd DK, Forbes SH (1998) Testing for wolf–coyote hybridization in the Rocky Mountains using mitochondrial DNA. Journal of Wildlife Management 62:683–689.

Pimlott, D.H., Shanon, J.A., and G.B. Kolenosky. 1969. The ecology of the timber wolf in Algonquin Provincial Park. Report No. 87. Ontario Ministry of Natural Resources, Toronto, Ontario, Canada.

Phillips, M., and V. Henry. 1992. Comments on red wolf taxonomy. Conservation Biology 6:596-599.

Pocock, R. 1935. The races of *Canis lupus*. Proceedings Zoological Society of London. Part 3; 647-686.

Potvin, F. 1988. Wolf movements and population dynamics in Papineau-Labelle Reserve, Québec. Canadian Journal of Zoology 66:1266-1273.

Potvin, F., H. Jolicoeur, L. Breton and R. Lemiuex. 1992a. Evaluation of an experimental wolf reduction and its impact on deer in Papineau-Labelle Reserve, Québec. Canadian Journal of Zoology 70**:** 1595-1603.

Potvin, F., H. Jolicoeur, and J. Huot. 1988. Wolf diet and prey selectivity during two periods for deer in Québec: decline versus expansion. Canadian Journal of Zoology 66:1274-1279.

Potvin, F., L. Breton, C. Pilon, and M. Mactuart. 1992b. Impact of an experimental wolf reduction on beaver in Papineau-Labelle. Reserve, Québec. Canadian Journal of Zoology 70:180-183.

Quinn, N. 2004. The presettlement hardwood forests and wildlife of Algonquin Provincial Park: A synthesis of historic evidence and recent research. Forestry Chronicle 80:705-717.

Quinn, N. 2005. Reconstructing changes in abundance of White-tailed Deer, *Odocoileus virgnianus,* Moose, *Alces alces,* and Beaver, *Castor Canadensis,* in Algonquin Park, Ontario, 1860-2004. Canadian Field-Naturalist 119: 330-342.

Reich, R. Wayne, and D. Goldstein. 1999. Genetic evidence for a recent origin by hybridization of red wolves. Molecular Ecology 8:139-144.

Rempel, R.S. 2011. Effects of climate change on moose populations: exploring the response horizon through biometric and systems models. Ecological Modelling 222: 3355-3365.

Rogic, A., N. Tessier, and F.-J. Lapointe. 2014. Identification of canids found within Parc national du Mont-Tremblant and its surroundings using microsatellite markers. University of Montreal, Ministère des Forêts, de la Faune et des Parcs. 30 p**.**

Roy M., E. Geffen, D. Smith, E. Ostrander, and R. Wayne. 1994. Patterns of differentiation and hybridization in North American Wolf-like Canids, revealed by analysis of microsatellite loci. Molecular Biology and Evolution 11:553–570.

Roy M., E. Geffen, D. Smith, and R. Wayne. 1996. Molecular genetics of pre-1940 red wolves. Conservation Biology 10:1413–1424.

Rutledge, L.Y. 2010a. Evolutionary origins, social structure, and hybridisation of the eastern wolf (*Canis lycaon*). Ph.D. dissertation, Trent University, Peterborough, Ontario, Canada. 187 pp.

Rutledge, L.Y., Patterson B.R., and B.N. White. 2010b. Analysis of *Canis* mitochondrial DNA demonstrates high concordance between the control region and ATPase genes. BMC Evolutionary Biology 10: 215.

Rutledge, L.Y., Garroway, C.J., Loveless, K.M., and B.R. Patterson. 2010c. Genetic differentiation of eastern wolves in Algonquin Park despite bridging gene flow between coyotes and Gray wolves. Heredity 105: 520-531.

Rutledge, L.Y., Bos, K.I., Pearce, R.J., White, B.N. 2010d. Genetic and morphometric analysis of sixteenth century *Canis* skull fragments: implications for historical eastern and Gray wolf distribution in North America. Conservation Genetics. 11: 1273-1281.

Rutledge, L.Y., Patterson, B.R., Mills, K.J., Loveless, K.M., Murray, D.L., and B.N. White. 2010e. Protection from harvesting restores the natural social structure of eastern wolf packs. Biological Conservation 143: 332-339.

Rutledge L. and B. White. 2013. Genetic characterization of Canis in Québec. Contrat de services abrégé 111720000. Final Report. 10 p.

Rutledge L. and B. White. 2014. Genetic characterization of Canis in Québec. Contrat de services abrégé 111720000. Final Report Addendum.14 p.

Rutledge, L.Y., White, B.N., Row, J.R., and B.R. Patterson. 2011. Intense harvesting of eastern wolves facilitated hybridisation with coyotes. Ecology and Evolution DOI: 10.1002/ece3.61.

Rutledge, L.Y., Wilson, P.J., Klütsch, C.F.C., Patterson, B.R., and B.N. White. 2012. Conservation genomics in perspective: a holistic approach to understanding *Canis* evolution in North America. Biological Conservation 155: 186-192.

Rutledge, L.Y., Devillard S., Boone, J.Q., Hohenlohe, P.A., and B.N. White. In Review. RAD sequencing and genomic simulations resolve hybrid origins within North America *Canis*. Biology Letters.

Rutledge, L.Y., Desy, G., Fryxell J., Patterson, B.R., and B.N. White. Distribution of eastern wolves refined with non-invasive sampling. in prep. Canadian Journal of Zoology.

Samson, C. 2001. COSEWIC Assessment Update Status Report of the Eastern Wolf (*Canis lupus lycaon*) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 17 pp.

Sand, H., Wikenros, C., Wabakken, P., and O. Liberg. 2006. Effects of hunting group size, snow depth and age on the success of wolves hunting moose. Animal Behaviour 72: 781-789.

Schmidt, K., Jędrzejewski, W., Theuerkauf, J., Kowalczyk, R., Okarma, H., and B. Jędrzejewski. 2008. Reproductive behaviour of wild-living wolves in Bialowieza Primeval Forest (Poland). Journal of Ethology 26: 69-78.

Schmitz, O.J., and G.B. Kolenosky. 1985. Wolves and coyotes in Ontario – morphological relationships and origins. Canadian Journal of Zoology 63:1130-1137.

Schreber, J. 1775. Die Säughthiere in Abbildungen nach der Natur mit Beschreibungen. Sweeter Theil. Tafeln. Erlangen. (Walther). Vol. 3, 353, plate 89. Erlangen.

Schwartz, M.K., and J.A. Vucetich. 2009. Molecules and beyond: assessing the distinctness of the Great Lakes wolf. Molecular Biology 18: 2307-2309.

Sears, H.J., Theberge, J.B., Theberge, M.T., Thornton, I., and G.D. Campbell. 2003. Landscape influence on *Canis* morphological and ecological variation in a coyote-wolf *C. lupus x latrans* hybrid zone, southeastern Ontario. Canadian Field-Naturalist 117: 589-600.

St. Louis, Antoine, 2012, pers. comm. *Email correspondence to L. Rutledge.* August 6, 2012. Biologiste des espèces menacees.

Coordonnateur de l'équipe de rétablissement des oiseaux de proie du Québec (ÉROP). MFFP, Québec, QC.

Steinberg, B. 2011. *E-mail correspondence to L. Rutledge.* May, 2011. Management Biologist, Algonquin Park, Ontario.

Stahler, D.R., Smith, D.w., and D.S. Guernsey. 2006. Foraging and feeding ecology of the Gray wolf (*Canis lupus*): lessons from Yellowstone National Park, Wyoming, USA. Journal of Nutrition 26: 1923S.

Stronen, A.V., Brook, R.K., Paquet, P.C., Mclachlan, S. 2007. Farmer attitudes toward wolves: implications for the role of predators in managing disease. Biological Conservation 135: 1-10.

Stronen, A.V. 2009. Dispersal in a Plain Landscape: Wolves in Southwestern Manitoba, Canada, PhD Dissertation. University of New Brunswick, Fredericton, New Brunswick, Canada.

Stronen, A.V., Forbes, G.J., Sallows, T., Goulet, G., Musiani, M., and P.C. Paquet. 2010. Wolf body mass, skull morphology, and mitochondrial DNA haplotypes in the Riding Mountain National Park region of Manitoba, Canada. Canadian Journal of Zoology 88: 496-507.

Stronen, A.V., (and 9 co-authors). 2012. Canid hybridization: contemporary evolution in human-modified landscapes. Ecology and Evolution 2: 2128-2140.

Tessier, N. 2015. Unpublished data. Ministère des Forêts, de la Faune et des Parcs (MFFP) du Québec.

Theberge, J.B. 1991. Ecological classification, status and management of the Gray Wolf, *Canis lupus,* in Canada. The Canadian Field-Naturalist 105: 459-463.

Theberge, J.B., Forbes, G.J., Barker, I.K., and T. Bollinger. 1994. Rabies in wolves of the Great-Lakes region. Journal of Wildlife Diseases 30: 563-566.

Theberge, J., and M. Theberge. 2004. The Wolves of Algonquin Park: A 12-Year Ecological Study. Publication Series Number 56, Department of Geogrpahy, University of Waterloo, Waterloo, Canada.

Theberge, J.B., Theberge, M.T., Vucetich, J.A., and P.C. Paquet. 2006. Pitfalls of applying adaptive management to a wolf population in Algonquin Provincial Park, Ontario. Environmental Management 37: 451-460.

Thompson, I.D., Fannigan, M.D., Wotton, B.M., and R. Suffling. 1998. The effects of climate change on landscape diversity: and example in Ontario Forests. Environmental Monitoring and Assessment 49: 213-233.

Toews, D.P., and A. Brelsford. 2012. The biogeography of mitochondrial and nuclear discordance in animals. Molecular Ecology 16: 3907-3930.

USFWS (United States Fish and Wildlife Service). 2015a. Endangered Species Act web page. http://www.fws.gov/endangered/laws-policies/index.html. [Accessed February 2015].

USFWS (United States Fish and Wildlife Service). 2015b. Red Wolf recovery web page. http://www.fws.gov/redwolf/documents.html. [Accessed February 2015].

USFWS, pers. comm. 2012. *Email correspondence to L Rutledge* May 21, 2012.

Vähä J-P, and C.R. Primmer. 2006. Efficiency of model-based Bayesian methods for detecting hybrid individuals under different hybridization scenarios and with different numbers of loci. Molecular Ecology 15: 63-72.

Van Zyll de Jong, C.G., and L. Carbyn. 1999. COSEWIC Status Report on the Gray Wolf (*Canis lupus*) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 61 pp.

Veradri, A., V. Lucchini, and E. Randi. 2006. Detecting introgressive hybridization between free-ranging domestic dogs and wild wolves (*Canis lupus*) by admixture linkage disequilibrium analysis. Molecular Ecology 15:2845-2855.

Villemure, M. 2003. Écologie et conservation du loup dans la région du parc national de la Mauricie. Maître és sciences. Université de Sherbrooke, Sherbrooke, Québec, Canada. 92 pp.

Villemure, M., pers. comm. 2011. *Email correspondence to L. Rutledge.* August, 2011. Resource Conservation Technician, La Mauricie National Park, Parks Canada, St-Mathieu-du Parc, QC.

Villemure, M., and M. Festa-Bianchet. 2002. Écologie du loup au parc national de La Mauricie. Report prepared for Parks Canada. Université de Sherbrooke. Département de Biologie, Sherbrooke, Québec. 130p.

Villemure, M., and H. Jolicoeur. 2004. First confirmed occurrence of a wolf, *Canis* lupus, south of the St. Lawrence River in over 100 years. Canadian Field-Naturalist 118: 608-610.

vonHoldt, B.M., Stahler, D.R., Smith, D.W., *et al.* 2008. The genealogy and genetic viability of reintroduced Yellowstone Gray wolves. Molecular Ecology 17: 252-274.

vonHoldt, B.M., (and 18 co-authors). 2011. A genome-wide perspective on the evolutionary history of enigmatic wolf-like canids. Genome Research 21: 1294-1305.

Vucetich, J., and P. Paquet. 2000. The demographic population viability of Algonquin wolves. Report prepared for The Algonquin Wolf Advisory Committee.

Way, J.G., Rutledge, L., Wheeldon, T., and B.N. White. 2010. Genetic characterization of eastern “coyotes” in eastern Massachusetts. Northeastern Naturalist.17: 189-204.

Way, J.G., and J. T. Bruskotter. 2012. Additional considerations for gray wolf management after their removal from Endangered Species Act protections. Journal of Wildlife Management 76: 457-461.

Wayne, R., and S. Jenks. 1991. Mitochondrial DNA analysis supports extensive hybridization of the endangered red wolf (*Canis rufus*). Nature 351:565-568.

Wayne, R., and N. Lehman. 1992. Mitochondrial DNA analysis of the Eastern Coyote: Origins and hybridization. Pp 9-22 *in* Ecology and Management of the Eastern Coyote. A. Boer (ed.). Wildlife Research Unit. Fredericton, NB. 194 pp.

Wheeldon, T. 2009. Genetic characterization of *Canis* populations in the western Great Lakes region. Masters thesis, Trent University, Peterborough, Ontario, Canada. 120 pp.

Wheeldon, T., and B.N. White. 2009. Genetic analysis of historical western Great Lakes region wolf samples reveals early *Canis lupus/lycaon* hybridisation. Biology Letters 5: 101-104.

Wheeldon, T.J., Patterson, B.R., and White, B.N. 2010. Sympatric wolf and coyote populations of the western Great Lakes region are reproductively isolated. Molecular Ecology. 19: 4428-4440.

Wheeldon, T.J., Rutledge, L.Y., Patterson, B.R., White, B.N., and Wilson, P.J. 2013. Y-chromosome evidence supports asymmetric dog introgression into eastern coyotes. Ecology and Evolution. 3:3005-3020.

Whittington, J., (and 6 co-authors). 2011. Caribou encounters with wolves increase near roads and trails: a time-to-event approach. Journal of Applied Ecology 48:1535-1542.

Williams, C.K., Ericsson, G., and T.A. Heberlein. 2002. A quantitative summary of attitudes toward wolves and their reintroduction (1972-2000). Wildlife Society Bulletin 30: 575-584.

Wilmers, C.C., Post, E., Peterson, R.O., and J.A. Vucetich. 2006. Predator disease out-break modulates top-down, bottom-up and climatic effects on herbivore population dynamics. Ecology Letters 9:383-389.

Wilmers, C.C., Post, E., and A. Hastings. 2007. The anatomy of predator-prey dynamics in a changing climate. Journal of Animal Ecology 76: 1037-1044.

Wilson, P.J., (and 14 co-authors). 2000. DNA profiles of the eastern Canadian wolf and the red wolf provide evidence for a common evolutionary history independent of the Gray wolf. Canadian Journal of Zoology 78: 2156-2166.

Wilson, P.J., Grewal, S., McFadden, T., Chambers, R.C., and B.N. White. 2003. Mitochondrial DNA extracted from eastern North American wolves killed in the 1800s is not of Gray Wolf origin. Canadian Journal of Zoology 81:936-940.

Wilson, P.J., Grewal, S.K., Mallory, F.F., and B.N. White. 2009. Genetic characterization of hybrid wolves across Ontario. Journal of Heredity. 100: S80-89.

Wilson, P.J., Rutledge, L.Y., Wheeldon, T.J., Patterson, B.R., and B.N. White. 2012. Y-chromosome evidence supports widespread signatures of three-species *Canis* hybridisation in eastern North America. Ecology and Evolution. DOI: 10.1002/ece3.301.

Woodroffe R., Cleaveland, S., Courtenay, O., Laurenson, M.K., and M. Artois. 2004. Infectious Disease: Infectious Disease in the management and Conservation of Wild Canids. Pp. 123-142 *in* Biology and Conservation of Wild Canids (D.W. MadDonald and C. Sillero-Zubiri (eds.). Oxford University Press, Oxford, UK.

Wydeven, A.P., Fuller, T.K., Weber, W., and K. MacDonald. 1998. The potential for wolf recovery in the northeastern United States via dispersal from southeastern Canada. Wildlife Society Bulletin 26: 776-784.

Wydeven, A.P., (and 6 co-authors). 2009. History, Population Growth, and Management of Wolves in Wisconsin. Pp. 87 - 105 *in* Recovery of Gray Wolves in the Great Lakes Region of the United States. A.P. Wydeven *et al*. (eds), Springer, DOI: 10.1007/978-0-387-85952-1.

Young S., and E. Goldman. 1944. The Wolves of North America. Dover Publications, New York, NY. 636 pp.

BIOGRAPHICAL SUMMARY OF REPORT WRITER

Linda Rutledge is a post-doctoral researcher and instructor in the Biology department at Trent University in Peterborough, Ontario. Her doctoral research focused on the evolutionary history, pack structure, and hybridization of Eastern Wolves in Algonquin Provincial Park. Dr. Rutledge's research interests focus on identifying evolutionary changes in species genomes that are indicative of behavioural responses, adaptation, hybridization, and speciation, especially as it applies to species at risk. She is also interested in how human influences impact the evolutionary trajectory of wildlife. Her current work involves utilizing comparative genomics of ancient and contemporary samples to identify genes responsible for ecological adaptations over space and time.

COLLECTIONS EXAMINED

The collections examined are documented throughout the report. Raw data used for analysis was from the Wolf and Coyote DNA Bank at Trent University (www.wolf.nrdpfc.ca).

Appendix A - Genetics of the Eastern Wolf

The identification of a distinct entity (*i.e.*, species, subspecies, Designatable Unit) using genetic techniques is complicated by development of new techniques and interpretations. The presence of unique haplotypes specific to a geographic area, and persisting over time, can indicate local adaptation and be used to validate a species. Computer simulation programs (e.g. STRUCTURE, Geneland) assign specimens into clusters of animals containing similar genotype. The latter method is based on a probability of assigning and is sensitive to sample size because a few samples may not be enough to differentiate as a distinct cluster within the larger sample set (Fogelqvist *et al.* 2010). As well, the ability to differentiate is a function of the relative differences among the sample set; a narrow subset of the range of genotypes means some distinct clusters will not be identified because those specimens were absent. Another aspect leading to confusion in *Canis* taxonomy is that several authors (*i.e*., vonHoldt *et al*. 2011, Koblmüller *et al*. 2009) have mixed Eastern Wolf samples in with Great Lakes Wolf and called them both *Canis lycaon*, and then concluded that Eastern Wolf or *C. lycaon* is a hybrid. However, under the 3-species hypothesis (see below), the Eastern Wolf is a valid species, and separate from Great Lakes Wolf, which is hybrid between Eastern Wolf and Gray Wolf.

<u>The 2-Species Hypothesis; The Eastern Wolf is a Hybrid</u>

Much of the research on *Canis* hybridization was initially related to whether the Red Wolf was a hybrid because Red Wolves were being protected under the US *Endangered Species Act* (ESA), but hybrids were not eligible for protection (USFWS 2015a). Wayne and Jenks (1991) and Roy *et al*. (1994) used the absence of unique mtDNA restriction sites (that would have united Red Wolf into a single clade) as evidence that the Red Wolf was a hybrid. In a rebuttal, Dowling *et al*. (1992) noted that flawed methodology and interpretation by Wayne and Jenks (1991) limited any such conclusion. In later work, the estimated period of hybridization that created Red Wolf occurred in the last 2500 years, and possibly in the last 250 years (Reich *et al*. 1999). vonHoldt *et al*. (2011) concluded that Red Wolf were hybrids, but it was noted by Rutledge *et al*. (2012) and Wilson *et al*. (2012) that von Holdt *et al*. (2012) used samples (n=12) from animals that existed after the recent Coyote introgression, which would be biased against identifying previously ‘pure’ Red Wolf. Although the debate continues, the Red Wolf remains on the US Endangered Species list.

The genetic studies on the Eastern Wolf were part of a Great Lakes region assessment of *Canis*, beginning in the 1990s (Lehman *et al*. 1991; Roy *et al*. 1994; Koblmüller *et al*. 2009). For example, using mtDNA restriction site polymorphisms on 226 samples collected from Manitoba to Maine, combined with 538 *Canis* samples from elsewhere in North America, Wayne and Lehman (1992) concluded that the Eastern Coyote was a hybrid, but also that all *Canis* in the Great Lakes region were hybrids. In 2009, Koblmüller *et al*. used maternal, paternal, and biparentally inherited markers to conclude that the large *Canis* in the Great Lakes region (Great Lakes Wolf) was a unique population or ecotype of Gray Wolf that experienced a high degree of introgression from Coyote and western Gray Wolf in ancient, and recent, times. vonHoldt *et al*. (2011) analyzed 48,000 single-nucleotide-polymorphisms (SNP) in *Canis* samples collected worldwide and concluded that Red Wolf and Great Lakes Wolf were not similar, and that Great Lakes Wolf was a hybrid with large amounts of Gray Wolf genome.

A criticism of earlier *Canis* taxonomic research was a reliance (by all researchers) on a single metric (mtDNA). Multiple metrics, such as the Y-chromosome, are now commonly used (e.g., Wilson *et al.* 2012). Another issue has been the low number of markers typically used (e.g., 12; Wilson *et al*. 2000, Rutledge *et al*. 2010b). The large number (48,000) used by vonHoldt *et al*. (2011) is cited as an improvement over earlier work (R. Wayne, in NCEAS 2014).

In summary, the 2-species hypothesis proposes that only two species (Coyote and Gray Wolf) exist and that hybrid events in recent and historical times have produced the array of hybrid *Canis*.

<u>The 3-Species Hypothesis; The Eastern Wolf is a Distinct Species</u>

The contention that Eastern Wolf and Red Wolf are valid species is derived from a hypothesis that three large *Canis* were present in North America. Based on sequence divergence of haplotypes Wilson *et al*. (2000) proposed that the ancestral progenitor of the Gray Wolf, Eastern Wolf/Red Wolf, and Coyote resided in North America. Approximately 1 – 2 million years ago, the Gray Wolf diverged from the ancestor and emigrated to Eurasia. The Coyote and Eastern Wolf/Red Wolf then diverged from each other between 150,000 to 300,000 years ago (Wilson *et al*. 2000), and the Gray Wolf returned to North America from Eurasia around 300,000 years ago (Kurten and Anderson 1980). Coyote were restricted to areas west of the Mississippi River, then moved northward and eastward in association with settlement and land-use practices by Europeans, and the extirpation of wolves in eastern North America. The reason there is an Eastern Coyote hybrid between the Eastern Wolf and 'western' Coyote is because they are closely related. The Great Lakes Wolf (or Great Lakes Boreal Wolf) is considered a hybrid between Eastern Wolf and Gray Wolf (Wilson *et al*. 2000, 2009; Wheeldon 2009).

The results of the above work was the basis for identifying the Eastern Wolf by COSEWIC in 2001 (Samson 2001). At present, the Eastern Wolf is listed as a subspecies of Gray Wolf (*Canis lupus lycaon*). However, genetic analyses in numerous projects noted the absence of enough *C. lupus* alleles and haplotypes in the Eastern Wolf/Red Wolf to consider Eastern Wolf as a subspecies of Gray Wolf (Lehman *et al*. 1991; Roy *et al*. 1994, 1996; Wilson *et al*. 2000, 2003; Grewal *et al.* 2004; vonHoldt *et al.* 2011). As well, mitochondrial DNA haplotypes not found in extant Gray Wolf populations were found in Eastern Wolf samples from the 1800s, a period before Coyote arrived (Wilson *et al*. 2003).

The initial basis for the 3-species hypothesis was work on 8 microsatellite loci and mtDNA control-region sequences from 68 samples collected in Algonquin Park, compared to Red Wolf (n=67), Texas Coyotes (n=24), and Northwest Territories Gray Wolf (n=67) (Wilson *et al*. 2000). *Canis* from Algonquin were differentiated from Gray Wolf, and Red Wolf was similar to Algonquin samples. Unlike the Great Lakes Wolf, mtDNA from Gray Wolf was not found in the central Ontario samples, as would be expected if these animals were hybrids of Gray Wolf x Coyote. Wilson *et al*. (2009) later analyzed mtDNA of 269 samples from Ontario (109 from Algonquin Park and 186 total from Eastern Wolf range), plus 393 *Canis* samples from elsewhere in North America, to conclude that a distinct *Canis* exists in central Ontario. Only 4 of 92 samples from Algonquin Park contained Gray Wolf haplotypes. Further work using Y-chromosome haplotypes in Eastern Wolf noted that these haplotypes are absent from western Coyote, which is evidence of a wolf evolving in eastern North America, consistent with the 3-species hypothesis (Wilson *et al*. 2012).

Other studies similarly found evidence that a *Canis* other than Gray Wolf was historically present in eastern North America (Bertorelle and Excoffier 1998). Eastern Wolf mtDNA has been found in 100-year-old samples from Wisconsin and Michigan (Leonard and Wayne 2008), and Wheeldon and White (2009) found Eastern Wolf mtDNA and admixed Gray Wolf - Eastern Wolf nuclear signature in 100-year-old wolf samples from Minnesota and Wisconsin. Genetic evidence suggests that Eastern Wolves may have been present in Maine and New York 100 years ago, prior to the eastward expansion of Coyotes (Wilson *et al.* 2003). Both genetic and morphometric analyses of samples excavated from a prehistoric (c.1530) Iroquois village in London, Ontario suggest that Eastern Wolves occurred in the Carolinian forests of southern Ontario prior to the arrival of European settlers (Rutledge *et al.* 2010d). A small *Canis* was present in the Pleistocene fossil record of eastern North America (Nowak 1995).

The conclusion in vonHoldt *et al*. (2011), and earlier papers, that the Eastern Wolf is a hybrid of Gray Wolf and Coyote has been challenged, or not supported, in recent publications (Rutledge *et al.* 2010c, 2012; Wilson *et al*. 2012; Benson *et al*. 2012, 2014). The basis of this challenge relates to the low number of samples from known Eastern Wolves. The contention from the 3-species hypothesis proponents is that the Eastern Wolf is confined to a relatively small area and samples taken from the Great Lakes region (*i.e.,* northern Ontario, Minnesota) and lumped in as a sample of Great Lakes Wolf (e.g., Koblmüller *et al*. 2009; vonHoldt *et al*. 2011) are not a valid measure of whether the Eastern Wolf exists. Sample size will influence the likelihood of differentiating a cluster of unique animals because the process involves individual genotypes being assigned to a taxon based on sample size and probability (Fogelqvist *et al.* 2010). In the Wayne and Lehman (1992) study, only 3 of the 764 samples were from the Algonquin Park area (of which two were from the same pack; G. Forbes, unpub. data), and 16 samples total were from the existing range of Eastern Wolf (Figure 4). Also, it is uncertain if these specimens were Eastern Wolf or admixed *Canis* (Eastern Coyote), and therefore how well Eastern Wolf were actually sampled. In the Koblmüller *et al*. (2009) study, few samples represented the *Canis* genotype before introgression of Coyote genes; only 4 of the 401 samples were from historical samples (1910 - 1916) in the present range of Eastern Wolf.

In a rebuttal to vonHoldt *et al*. (2011), Rutledge *et al*. (2012) noted that the two samples from Algonquin Park were insufficient to differentiate Eastern Wolf. However, when a phylogenetic re-analysis of the 48K SNP data in von Holdt *et al.* (2011) was constructed with the two samples, but then combined with additional local samples, the two Eastern Wolves from Algonquin Park now clustered independently of other *Canis* groups and were located basal to Red Wolves and Coyotes within a North American lineage (Rutledge *et al.* 2012), indicating ancestry with Coyote, and as expected in a 3-species hypothesis. As well, the basal pattern was similar to that seen with both mtDNA (Rutledge *et al.* 2010b) and the Y-chromosome (Wilson *et al.* 2012). These results provide maternal, paternal, and bi-parental genetic evidence for the Eastern Wolf as a species. Most recently, an analysis of 127K genome-wide SNPs demonstrated through hybrid simulations that the Eastern Wolf is a distinct species, and inclusion of it as a third species resolves the hybrid origins of Great Lakes-Boreal Wolves and Eastern Coyotes (Rutledge *et al.* in revision).

As well, Rutledge *et al*. (2012) noted that vonHoldt *et al.* (2011) used a method that assumes a 2-species model which only allows ancestry to be divided between Gray Wolves and Coyotes, a design which could not delineate Eastern Wolf. As well, Rutledge *et al*. 2012) contends that there is a biased assumption that the SNP panel ascertained from the domestic Dog (*Canis lupus familiaris*) genome captures the true variability in wild *Canis* species.

Although the debate on *Canis* taxonomy continues, the evidence below is considered compelling enough to consider the Eastern Wolf as a valid taxonomic entity:

1. Two Eastern Wolf mtDNA haplotypes (C1 and C3) cluster monophyletically and occur basal to all other North American evolved (Coyote/Red Wolf) haplotypes (Rutledge *et al.* 2010b).
2. Three Eastern Wolf Y-chromosome haplotypes (4AA, 4BB, 4BR) exist that are more closely associated with Coyotes, but are as divergent from them as Coyotes are from Gray Wolves (Wilson *et al.* 2012).
3. The monophyletic basal clustering pattern observed in the phylogenetic analysis of wolves from Algonquin Park profiled at 48K SNPs (Rutledge *et al.* 2012).
4. There is independent clustering of autosomal microsatellites analyzed in wolves from Algonquin Park (Rutledge *et al.* 2010c; Rutledge *et al.* 2012; Benson *et al*. 2012).
5. There is independent clustering and lack of overlap with simulated Gray Wolf-Coyote hybrids based on 127K genome-wide SNPs (Rutledge *et al.* In Revision).
6. Out of a sample size that included canids from Algonquin Park (n=37), North American Gray Wolves (n=175), European Gray Wolves (n=222), and Coyotes from across North America (n=70), the identification of three unique haplotypes of the major-histocompatibility complex (MHC), a group of genes involved in immune response, in wolves from Algonquin Park suggests that the Algonquin Wolf is a distinctly different species from other canids (Kennedy pers. comm. 2012).

7. Although Coyote-like mtDNA is introgressed into Algonquin Park wolves (Rutledge *et al.* 2010c), there is little evidence of introgression of nuclear DNA (Rutledge *et al.* 2011). This discordance between mtDNA and nuclear DNA is common in animal systems (see Toews and Brelsord 2012 for a review) and it remains unclear if the Coyote-like mtDNA presence in Eastern Wolf is due to incomplete lineage sorting due to their recent divergence (150,000 – 300,000 years ago (Wilson *et al.* 2000)).
8. Morphological (Kolenosky and Standfield 1975; Schmitz and Kolenosky 1985; Rutledge *et al.* 2010e; Benson *et al.* 2012) evidence supports the existence of the Eastern Wolf (see Morphological Description).
9. A distinct canid has been recognized in the Great Lakes – Eastern North America region since the mid-1700s (see Taxonomic Validity) and animals with the same genetic characteristics as today's Eastern Wolf have been found in samples from over 100 years ago (Wilson *et al*. 2003), and previous to the arrival of Coyote. In Québec, the Coyote was not recorded until the 1940s (Naughton 2012) but the type specimen for *Canis lycaon* was collected in Québec in 1761 (see Taxonomic Validity). In the 2-species hypothesis, Eastern Wolf is the product of Coyote breeding with Gray Wolf, but, based on historical evidence, the Eastern Wolf was already present before Coyotes, suggesting Eastern Wolf is a true species, and not the result of Coyote and Gray Wolf hybridization (Rutledge *et al*. 2010d).
10. Aboriginal traditional knowledge recognizes that different types of Canids existed in the region before European contact (Lickers pers. comm).
11. Genetic analysis of skull fragments suggests Eastern Wolf (and not Gray Wolf) have existed in southwestern Ontario since the 1500s (Rutledge *et al*. 2010d).
12. The larger *Canis* that bred with 'western' Coyote is believed to be the Eastern Wolf because Gray Wolf and Coyote are not believed to naturally interbreed in the wild (Kyle *et al*. 2007; Mech 2011). Such breeding would be necessary to create an Eastern Wolf hybrid. Mech *et al*. (2014) artificially inseminated female 'western' Coyote with semen from western Wolves and produced pups, which proved cross-breeding is possible, but the results were mixed because 8 of 9 females exhibited abnormal behaviour and/or absorbed fetuses.
13. Gray Wolf and Coyote are sympatric in southwestern North America (i.e. Mexican Wolf, *C. lupus baileyi*) and northwestern North America, but hybridization is not evident (Hedrick *et al*. 1997; Garcia-Moreno *et al*. 1996; Pilgrim *et al*. 1998), which is contrary to the 2-species hypothesis that a hybrid is produced when Gray Wolf and Coyote are sympatric. Hybridization is more likely for closely related species, which supports the conclusion of the 3-species hypothesis that Eastern Wolf/Red Wolf and Coyote hybridize in eastern North America because they are more related to each other than they are to Gray Wolf (Wilson *et al.* 2000).

Possible Mechanism for the Maintenance of a Distinct *Canis*

The Eastern Wolves identified by genetic analyses are almost all found in protected areas, even though sampling was conducted over a wide range of park, and non-park, areas (see **Search Effort**; Figure 4, 6). The mechanism to create and maintain unique species among closely related *Canis* types is unknown but there is evidence that introgression of Coyote/Eastern Coyote genes is facilitated by a change in pack dynamics. It is hypothesized that excessive mortality of breeding animals alters the socially based breeding structure of the pack (Rutledge *et al*. 2010c, 2011; Benson *et al*. 2013a, 2014). Typically, only the dominant (alpha) pair breed, and breeder loss can lead to dissolution of pack cohesion and changes in mating patterns (Brainerd *et al.* 2008). Despite introgression in some individuals (Rutledge *et al*. 2010c**,** Grewal *et al.* 2004), the Eastern Wolves in Algonquin Park have retained a genetically distinct signature for at least 50 years (Rutledge *et al.* 2011). Wolves in this >7000km^2 park have been protected from hunting and trapping for much of this time. During the 1980s and 1990s, many Park wolves were killed when they followed Deer out of the east side of the Park (Forbes and Theberge 1996b). Those high mortality rates have been implicated in the introgression of Coyote mtDNA, and appearance of Eastern Coyote nuclear DNA during this period, because the Eastern Wolf nuclear signature was restored after a hunting and trapping ban in areas adjacent to the Park was implemented in 2001 (Rutledge *et al.* 2011). Similarly, Eastern Wolves dispersing from western regions of the Park are highly vulnerable to harvest mortality (Benson *et al.* 2014), despite some residency noted in the unprotected areas of Wildlife Management Unit (WMU) 47 (n=3) and WMU49 (n=1) (Benson *et al.* 2012). Ongoing hybridization with Eastern Coyotes has been curtailed by protection that presumably allows for conspecific mates to be more readily found (Rutledge *et al.* 2010c, 2011).

Despite evidence of gene flow between *Canis* types in general, there is substantial genetic and morphological structuring within Eastern Wolves. Ecological differences in habitat and prey base, as well as conspecific mate choice, may drive the divergence (Rutledge *et al.* 2010c). The levels of heterozygosity, based on autosomal microsatellite markers, are generally high (Ho = 0.645; SE = 0.04, Rutledge *et al.* 2010c) and although traditional measures of genetic differentiation such as Fst are relatively low (Fst between Eastern Wolves and Great Lakes-Boreal Wolves = 0.105; and between Eastern Wolves and Eastern Coyotes = 0.052), the differences are statistically significant ($p<0.001$). Also, new measures based on allele sharing (Jost 2008) suggest higher levels of differentiation exist between Eastern Wolves and Great Lakes-Boreal Wolves (Jost D = 0.207) than between Eastern Wolves and Eastern Coyotes (Jost D = 0.090) (Rutledge *et al.* 2010c). Bayesian and multivariate clustering analyses based on autosomal microsatellites reveal substantial differentiation of Eastern Wolves in Algonquin Park from *Canis* types in neighbouring regions, despite the lack of any physical barrier (Rutledge *et al.* 2010c; Benson *et al.* 2012). Eastern Wolf packs are spatially segregated from each other and from other *Canis* types (Benson and Patterson 2013a).

The unique genetic signature may also be related to assortative mating and/or selection against nuclear introgression from Eastern Coyotes (Rutledge *et al.* 2010c) because Eastern Wolves are ecologically differentiated based on habitat and the energetic requirements associated with larger size of prey (Benson *et al.* 2012; Rutledge *et al.* 2010c). Loveless (2010) suggested that the restoration of a natural social structure in Algonquin Park (Rutledge *et al.* 2010e) may be responsible for the improved efficiency at Moose predation via learning passed down through family members. The unique genetic signature is unlikely to be due to genetic drift because genetic drift is most commonly associated with isolated populations, but Algonquin Park is not isolated. Gene flow could occur across the region but the *Canis* genotype in Algonquin Park has been maintained at least since the 1960s, likely due to assortative mating (Rutledge *et al*. 2011). Also, genetic diversity is relatively high (observed heterozygosity = 0.645; Rutledge *et al*. 2010c) and there is no evidence of inbreeding Rutledge *et al*. 2010e)

Red Wolf and Eastern Wolf

Under the 3-species hypothesis, it is possible that the Eastern Wolf and the Red Wolf are the same species. Evidence from autosomal microsatellites suggests overlap in their genetic signature (Wilson *et al.* 2000; Kyle *et al*. 2006, 2008; Murray and Waits 2008; Rutledge *et al.* 2012), and phylogenetic analysis of 48K SNP data suggests Algonquin Wolves are basal to Red Wolves within a North American lineage (Rutledge *et al.* 2012). The range likely would have included eastern regions of the United States and southern regions of Ontario and Québec, a range largely consistent with the eastern temperate forests and the historical distribution of Deer (Nowak 1995, 2002, Figure 3).

The extant Red Wolf population has been produced by a captive breeding program that originated with 14 animals captured in the Texas-Louisiana region during the 1970s. They were identified as Red Wolf based on morphometrics and vocalizations (McCarley and Carley 1979), and some of their descendants were released into North Carolina, and are now reproducing (USFWS 2015b). However, the original breeders contained Coyote (vonHoldt *et al.* 2011), Dog and/or Gray Wolf genetic material (Hailer and Leonard 2008; Wilson *et al.* 2012) and despite controlled breeding management, there is concern that the existing Red Wolf sample is not a full representation of the Red Wolf genome. As such, the ability to use extant genetic samples to assess whether they were the same species is compromised.

Endangered Species Listing

The taxonomic issue has affected Endangered Species listing in the United States. In May 2011, the United States Fish and Wildlife Service (USFWS) formally recognized the Eastern Wolf as a distinct species (*C. lycaon*), but retracted the statement in December, 2011. A review of *Canis* species, subspecies, and hybrid taxonomy in North America was then produced (Chambers *et al.* 2012), which formed the basis for a proposed ruling on listing by the USFWS. Based on the findings of vonHoldt *et al*. (2011), the USFWS undertook an expert panel exercise (NCEAS 2014) to discuss the Chambers *et al*. (2012) review. Of note, the Chambers *et al*. (2012) review was not a review of Eastern Wolf (as defined in this COSEWIC report), because Chambers *et al*. (2012) combined all *Canis* in the Québec-Great Lakes region into one ‘Eastern Wolf (*Canis lycaon*)’, whereas it is the contention of this report that Eastern Wolf only refers to the *Canis* in central Ontario, and southern Québec (see Appendix B; Figure 4). The conclusion of the NCEAS (2014) report was that there was no consensus on *Canis* taxonomy, with proponents of the ‘2-species’ or ‘3-species’ hypotheses ‘agreeing to disagree’ (NCEAS 2014). The report does not conclude that Eastern Wolf is an invalid species but only that there is a lack of consensus on *Canis* taxonomy, and that Chambers *et al*. (2012) did not reflect this perspective well enough, and therefore the proposed ruling is not based on the ‘best available science’.

Notwithstanding the debate, there is consensus that extant populations of both the Red Wolf and Eastern Wolf have some degree of Coyote genome. As well, it is agreed that the Eastern Coyote is a hybrid, which now exists across eastern North America. These *Canis* have established through natural range expansion and interaction. The issue of hybridization events, especially in human-modified environments, raises questions on the limitations of the species concept and taxonomic nomenclature as a basis for managing species that are not ‘pure’ (Wilson *et al*. 2012). The controversy over including possible hybrids such as the Red Wolf in Endangered Species protection resulted in numerous arguments for identifying species based on ecological and behavioural characteristics, and not simply genetic ones (e.g., Theberge 1991; Nowak 1992; Phillips and Henry 1992). Dowling *et al*. (1992) noted that the intent of the ESA was to protect distinctive forms, regardless of how well they fit into the species concept. The US *Endangered Species Act* recognizes evolutionary significant units, and implementation of the Canadian *Species at Risk Act* recognizes a broader definition of Wildlife Species, both of which facilitate protection of distinct and significant entities below the species level.

Appendix B - Identification of Eastern Wolf Individuals

Individual animals need to be assigned to the population of Eastern Wolf in Canada because the range of Eastern Wolf contains *Canis* of mixed genotype. The assignment of individuals as Eastern Wolves is based on an analysis of bi-parentally inherited nuclear autosomal microsatellite genetic markers because of: a) the introgression of Eastern Wolf mtDNA and Y-chromosome haplotypes into Great Lakes-Boreal Wolves (Rutledge *et al.* 2010c) and Eastern Coyotes (Way *et al.* 2010) across their ranges; b) the mtDNA-nuclear DNA discordance known to occur throughout animal systems, including the *Canis* genus (Toews and Brelsford 2012); and c) the potential for incomplete lineage sorting of mtDNA between Eastern Wolves and Coyotes (Wheeldon and White 2009).

Canis-type identification routinely utilizes 12 autosomal microsatellite markers to conduct assignment tests under a Bayesian analytical framework implemented in the software program STRUCTURE 2.3 (Hubisz *et al.* 2009). Based on simulation analysis tests (Rutledge *et al.* 2010c), an assignment score of Q≥0.8 (where Q is the probability of belonging to a cluster) from the program STRUCTURE 2.3 (Hubisz *et al.* 2009) is set as the criteria for accurate Eastern Wolf identification. Individuals with Q<0.8 are considered admixed (*i.e.*, a mixture of nuclear alleles from at least two of the three *Canis* types). With this approach, samples can be assigned to one of three *Canis* types: Eastern Wolf, Great Lakes-Boreal Wolf, or Eastern Coyote, or identified as "admixed", meaning hybridization was evident between 2 or 3 of the *Canis* types.

The use of Q<0.8 as a threshold is based on basic patterns of inheritance, support from literature, analyses, and some assumptions. The basic patterns of inheritance refers to any F1 hybrid possessing a Q=0.5, and, if backcrossed with a parent, becomes Q=0.75. A Q>0.8 avoids capturing such events. The Q value threshold concept has been validated elsewhere (e.g., Vähä and Primmer 2006) as well as with hybrid simulation analysis that indicated a strong demarcation of Eastern Wolf within, and outside, Algonquin Park, a result believed to be related to effects of Eastern Wolf harvest and rates of Coyote introgression (see Appendix A – 'Mechanism'). Benson *et al*. (2012) tested the validity of Q<0.8 assignments using PCA methods and found a 90% compliance between assignments from STRUCTURE, and PCA. The Q value approach is a common approach for identifying *Canis* types (e.g., Veradri *et al*. 2006; Benson *et al*. 2012; Wheeldon *et al.* 2013).

The Q value threshold approach requires an assumption of what a 'pure' Eastern Wolf genotype would be. However, we lack enough specimens that have been collected before Coyotes were present to characterize a pure Eastern Wolf. The use of Q≥0.8 as a threshold for identifying Eastern Wolf determines the number of animals and sites containing what is considered an Eastern Wolf. Although Q≥0.8 has value as a threshold, a map of animals with Q=0.75 could identify more animals, and consequently, the extent to which Eastern Wolf are restricted to protected areas, as appears to be the case. Production of a map was not possible because sites on the 457 samples analyzed in Québec (Rutledge and White 2014) were only available for the 11 specimens with Q≥0.8. In the Algonquin Park area, if the Q value was changed to either 0.75 and/or 0.85, some sampled regions vary by > 10% in the number of animals assigned to one category of *Canis*, or another (C. Kyle, unpubl.

data). Further, in some regions sampled that have no Q>0.8 Eastern Wolf, there are Q>0.75 animals. It is possible then that the population size of Eastern Wolf varies, but only a small amount from the estimate based on Q≥0.8 (Table 2). The range (extent of occurrence) likely would not change because it already encompasses a large area with few records. In summary, the use of Q≥0.8 has the most support, and appears to capture the distribution and population size relatively well.

Appendix C: Threat Calculator

Species	Eastern Wolf		
Date:	12/02/2015		
Assessor(s):	Members: Dave Fraser (moderator), Graham Forbes (TM SSC Co-chair), Scott Reid (ON), Isabelle Gauthier (QC) External Experts: Jeff Bowman (TM SSC member), Brent Patterson (ON), Nathalie Tessier (QC), Antoine St-Louis (QC), Sylvain Giguère (CWS-QC), Pierre-André Bernier (CWS-QC), John Benson		

Overall Threat Impact Calculation Help:

Threat Impact		Level 1 Threat Impact Counts: high range	Level 1 Threat Impact Counts: low range
A	Very High	0	0
B	High	1	0
C	Medium	2	2
D	Low	1	2
Calculated Overall Threat Impact:		Very High	High

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
1	Residential & commercial development	D	Low	Small (1-10%)	Extreme (71-100%)	High (Continuing)	
1.1	Housing & urban areas	D	Low	Small (1-10%)	Extreme (71-100%)	High (Continuing)	Based on the species extent of occurrence from Figure 4 of the report. Scope: all in agreement that new development would be less than 10% Severity: based on the population to be affected by the new housing and urban areas (not just counting mortality) * impact is extremely high when we consider new urban development, however, wolves can use cottages/housing area that remain relatively rural * ON has no Eastern Wolf present in urban areas * QC is expecting more cottage development **Note: May need to revisit based on QC uncertainty; QC are considering only mortality based on new development (thus negligible) as wolves would leave the area.**
1.2	Commercial & industrial areas		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	Scope * QC suggest small (1-10%) but can agree with negligible * there is a possibilty of new shopping centres in ON, but doesn't believe it will push scope above 1%
1.3	Tourism & recreation areas	D	Low	Small (1-10%)	Serious - Moderate (11-70%)	High (Continuing)	Scope * QC - small (1-10%) * ON is saturated with golf courses and probably won't support anymore in the next 10 years; small (1-10%) based on other recreation (ex. Summer camps, cottage country recreation etc.)

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
2	Agriculture & aquaculture		Negligible	Negligible (<1%)	Serious - Slight (1-70%)	Moderate (Possibly in the short term, < 10 yrs)	
2.1	Annual & perennial non-timber crops		Negligible	Negligible (<1%)	Serious - Slight (1-70%)	Moderate (Possibly in the short term, < 10 yrs)	Scope: ON/QC agreement of negligible Severity: * most of the wolves are within protected area, however, with limited distribution data when wolves move between the parks, a range is used to indicate uncertainty * ON forest covers are increasing and agriculture extent is going down and again, without knowing where wolves move outside the park, there is a lot of uncertainty
2.2	Wood & pulp plantations		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	* ON: not an issue * QC: there will be some threat
2.3	Livestock farming & ranching		Negligible	Negligible (<1%)	Unknown	High (Continuing)	Severity * ON: livestock might be increasing * QC: between Algonquin and parks in the eastern range, there is a lot of uncertainty
3	Energy production & mining		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	
3.1	Oil & gas drilling		Negligible	Negligible (<1%)	Negligible (<1%)	Insignificant/Negligible (Past or no direct effect)	* ON: not aware of any issue * QC: believes there will be a little bit
3.2	Mining & quarrying		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	Scope * ON: could be a bigger iimpact but on the low end of small (1-10%) but based on Figure 4a, most occur in QC and will agree with negligible (<1%)
3.3	Renewable energy						
4	Transportation & service corridors	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	
4.1	Roads & railroads	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	Scope: pervasive (71-100%) because this includes all roads (including logging/mining) Severity: range used to denote uncertainty * ON: road kill certainly happens but not a major cause of decline in population level. There have been a few kills recently (ex. Hwy 116) but it's a small number * QC: there are few data but numbers could be higher. One recent study found 6 wolves killed out of 60; although uncertain if wolves killed were eastern or a hybrid.
4.2	Utility & service lines		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	Scope: only looking at new service and utility lines * ON: no new development that would affect population; < 1% * QC: close to 1% but not aware in the coming years if more area would be impacted
5	Biological resource use	BC	High - Medium	Large (31-70%)	Serious - Moderate (11-70%)	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
5.1	Hunting & collecting terrestrial animals	BC	High - Medium	Large (31-70%)	Serious - Moderate (11-70%)	High (Continuing)	Scope: takes into account both legal and illegal hunting and bycatch. A large proportion of the population is found within Algonquin Park, pervasive (71-100%) would be too high * ON: once wolves leaves the protected area, they fair very poorly. On the eastern end, there is no poaching/harvesting allowed Severity: range used to denote uncertainty * QC: depends on the different group and the proportion that move outside the protected area; may not be high in some places
5.2	Gathering terrestrial plants						Not an issue
5.3	Logging & wood harvesting						Not an issue. * ON: could be a benefit over the 10 year period
5.4	Fishing & harvesting aquatic resources						Not an issue
6	Human intrusions & disturbance		Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	
6.1	Recreational activities		Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	Scope * QC: snowmobiling activity is very high * ON: high if we include activities like canoeing and other cottage recreation
6.2	War, civil unrest & military exercises						Not an issue
6.3	Work & other activities						Not an issue
7	Natural system modifications		Negligible	Restricted - Small (1-30%)	Negligible (<1%)	High (Continuing)	
7.1	Fire & fire suppression		Negligible	Restricted - Small (1-30%)	Negligible (<1%)	High (Continuing)	
7.2	Dams & water management/use		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	
8	Invasive & other problematic species & genes	C	Medium	Pervasive (71-100%)	Moderate (11-30%)	High (Continuing)	
8.1	Invasive non-native/alien species		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Scope * ON would be pervasive (71-100%). Note: numbers based on studies in 2007 (which was a bad year); probably 11% died. * QC: has no data Severity: Unknown * ON can provide precise numbers on mortality rate but don't have a better guess for severity **Note: coyote genetic issue dealt with in 8.3**

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
8.2	Problematic native species		Unknown	Large (31-70%)	Unknown	High (Continuing)	Scope: what % of Eastern Wolf experience problematic native species? * ON: all the ones outside of Algonquin Park **Note: This is a limiting factor rather than a threat; discussed in report as limiting factor**
8.3	Introduced genetic material	C	Medium	Pervasive (71-100%)	Moderate (11-30%)	High (Continuing)	Severity * ON: potentially any wolves that leave Agonquin Park would have higher than 30% of dog/coyote gene but can agree with the 11-30% range for all population
9	Pollution						
9.4	Garbage & solid waste		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	Not counting towards overall calculator * score based QC, but this could actually have a positive effect * ON: landfill/garbage does have an impact on wolves (both postively and negatively)
9.5	Air-borne pollutants						
9.6	Excess energy						
10	Geological events						Not an issue
11	Climate change & severe weather						Unknown. Changes to climate haven't been long enough to see changes. Long term moose density (and deer) could change and affect the wolf population.
11.1	Habitat shifting & alteration						Unknown