GENETIC CHARACTERIZATION OF *CANIS* POPULATIONS IN THE WESTERN GREAT LAKES REGION

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ABSTRACT

Genetic characterization of *Canis* populations in the western Great Lakes region

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The genetic status of *Canis* populations in the western Great Lakes Region (WGLR) has been debated for years. This thesis examines the genetic composition of *Canis* in the WGLR to determine which *Canis* species contributed to the genomes of extant and pre-recovery WGLR wolf populations. Analysis of microsatellite genotypes, and mitochondrial DNA and Y-chromosome sequences, revealed that the majority of the extant WGLR canids sampled are part of a large wolf population extending across Michigan, Wisconsin, Minnesota and northwestern Ontario, having predominantly eastern wolf (*C. lycaon*) and gray wolf (*C. lupus*) ancestry. The extant WGLR wolf population was determined to be composed of gray-eastern wolf hybrids that do not breed with sympatric coyotes (*C. latrans*). Genetic profiles of three century-old wolves from the WGLR were similar to those of extant animals in the region, and this was interpreted to suggest that current WGLR wolves are representative of the pre-recovery population.

Keywords: hybridization, eastern wolf, gray wolf, coyote, mitochondrial haplotype, microsatellite genotype

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Chapter 1: General Introduction

Overview

Hybridization between species of the genus *Canis* has been clearly documented based on morphological and genetic data (e.g. Wayne and Vila 2003). The most notable example of *Canis* species hybridization occurs between wolves and coyotes in northeastern North America (e.g. Lehman *et al.* 1991; Wilson *et al.* 2008). Hybridization between *Canis* species has led to issues regarding the taxonomic distinction of wolf and coyote populations and has affected their management and conservation because of: 1) inaccurate assessment of relative population sizes; 2) difficulty enforcing the protection of species that have hybridized with non-protected species, given the lack of definitive hybrid policies; and 3) uncertainty regarding whether hybrids warrant protection (e.g. natural versus human-caused hybridization). Presently, hybridization may be the most important issue regarding the conservation and management of wolves in North America (e.g. Wayne and Vila 2003; Leonard and Wayne 2008).

Hybridization

Hybridization is generally defined as the "interbreeding of hetero-specific individuals from genetically distinct populations regardless of the taxonomic status of the populations", but hybridization has also been used to describe matings between individuals of different subspecies or populations, which although they may be taxonomically indistinguishable, can differ genetically (Rhymer and Simberloff 1996). When hybridization among species/populations is extensive and ongoing, hybrid swarms may develop, which are populations of individuals in which "introgression has occurred to various degrees by varying numbers of generations of backcrossing to one or both parental taxa, in addition to mating among the hybrids themselves" (Rhymer and Simberloff 1996). Hybridization is an important issue for researchers because it can have significant implications for the conservation and management of threatened or endangered species.

Hybridization can be a natural evolutionary process, but it can also be exacerbated by human activities such as habitat modification, fragmentation, and the introduction of non-native plants and animals (Allendorf *et al.* 2001). The interaction of these activities results in the breakdown of geographic barriers and reproductive isolation between allopatric species, allowing them to interbreed (Fox 2008). The processes of habitat modification and fragmentation homogenize natural environments, removing ecological niches and promoting hybridization (Fox 2008). Species may be more susceptible to hybridization when operational sex ratios are strongly skewed or in areas where population density of conspecifics is low, i.e. near their distribution fringe (Reyer 2008). Hybrid zones may develop at the contact point of two species and progressively expand into their respective distributions given continued hybridization.

Hybridization is generally regarded as a process that reduces biodiversity, however, it can also create biodiversity by combining traits of species and facilitating evolutionary adaptation. Hybridization can restore genetic variation to populations that have lost variation due to bottlenecks, genetic drift or inbreeding, however, hybridization can also be a threat to genetically distinct populations (e.g. gene swamping of red wolves by coyotes: Wayne and Vila 2003; Waits and Murray 2007; Kyle *et al.* 2008).

Hybridization has generally been assessed based on the presence of phenotypic features, morphology or behavior intermediate to the hybridizing taxa, however, hybrid individuals are not always intermediate to the parents based on these measures of differentiation (Allendorf *et al.* 2001). Advances in molecular genetics have allowed researchers to identify and quantify levels of genetic admixture between hybridizing species/populations for a variety of taxa: wildcats and domestic cats (Pierpaoli *et al.* 2003); mottled ducks and mallards (Williams *et al*. 2005); lynx and bobcats (Schwartz *et al.* 2004); chukars and partridges (Barilani *et al.* 2007); rainbow trout and cutthroat trout (Young *et al.* 2001); wolves and dogs (Andersone *et al.* 2002; Randi and Lucchini 2002); eastern wolves and coyotes (Lehman *et al.* 1991, Roy *et al.* 1994, Wilson *et al.* 2008).

In North America, where ranges of several *Canis* species overlap, various degrees of hybridization over time has led to a continuum of genetic and morphological differences throughout the landscape, perhaps most notably in northeastern North America (e.g. Wayne and Vila 2003). The Federal Wildlife Service in the United States has no official position on wolf-coyote hybrids but actions suggest protection is not considered warranted (Adkins Giese 2006). The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designated the eastern wolf (*Canis lycaon*) a species of special concern federally in 2001 under the Species at Risk Act, recognizing that the eastern wolf may be threatened by hybridization with coyotes (COSEWIC 2006). Similarly, the Committee on the Status of Species at Risk in Ontario (COSSARO) designated the eastern wolf a species of special concern in 2004 on the Species at Risk in Ontario List, recognizing that eastern wolves have hybridized with both gray wolves and coyotes (OMNR 2005). Presently, wolf-coyote hybrids have no official federal status to warrant protection in Canada (COSEWIC 2006), but they are protected in Ontario under the *Fish and Wildlife Conservation Act* (1997) (OMNR 2005).

Canis Taxonomy and Genetics

There has been much debate concerning the taxonomic status of *Canis* species in North America over the past century. Previous taxonomic designations were largely based on morphological differences and variation in phenotypic traits (Miller 1912; Pocock 1935; Goldman 1944; Nowak 1979), notably resulting in disagreement over the number of gray wolf (*Canis lupus*) subspecies (Hall 1981; Nowak 1995). Genetic studies conducted over the last two decades have provided further insight into the evolutionary history of *Canis* species, both regionally and globally (see Wayne and Vila 2003). It is generally accepted that the progenitor of the gray wolf migrated from North America to Eurasia and evolved there approximately 1 to 2 million years ago, and later returned to North America via the Bering land bridge (Nowak 1979; Lehman *et al.* 1991; Wilson *et al.* 2000). Based on genetic evidence the eastern wolf (*Canis lycaon*) was shown to be a distinct species, conspecific to the red wolf (*Canis rufus*), that evolved in North America sharing a common lineage with the western coyote (*Canis latrans*) until 150 000 to 300 000 years ago (Wilson *et al.* 2000) (Figure 1.1). Early taxonomic descriptions had characterized the eastern wolf as a distinct species *C. lycaon* (Miller 1912; Pocock 1935), however it was later designated a subspecies of the gray wolf, *C. lupus lycaon* (Young and Goldman 1944), and gray wolf subspecies status was maintained until recently (Wilson *et al.* 2000; Kyle *et al.* 2006).

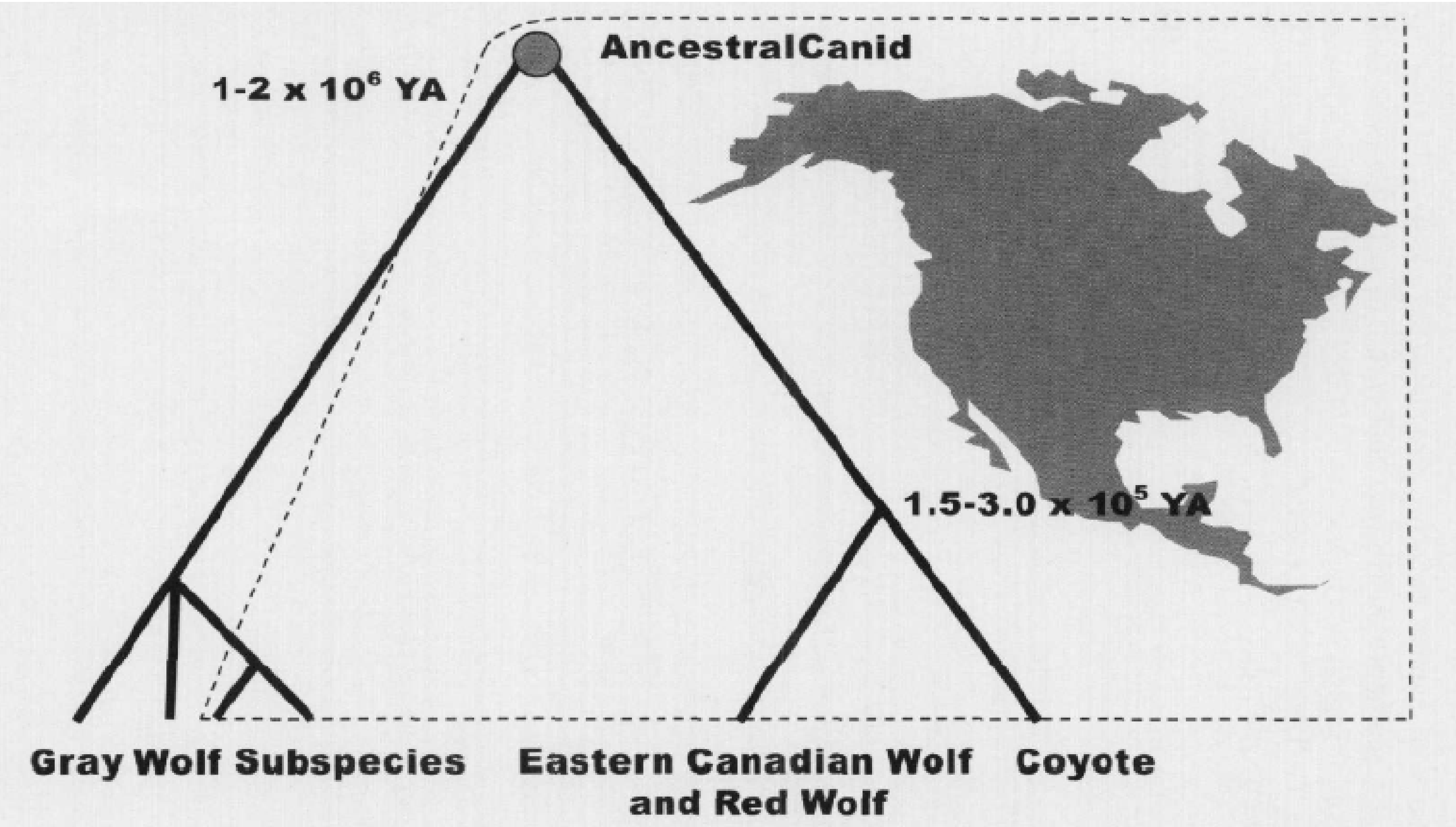


Figure 1.1: Evolution of *Canis* species in North America. Taken from Wilson *et al.* 2000 (Figure 6).

Prior to European settlement of North America, the gray wolf was thought to occupy most of the continent with the exception of the eastern deciduous forests (Nowak 1995), where a morphologically distinct species of wolf was recognized (Young and Goldman 1944; Peterson 1966; Kolenosky and Standfield 1975; Theberge 1991; Nowak 2002), representing the eastern wolf. Coyotes were historically restricted to the plains and deserts of central North America (Bekoff and Wells 1986; Moore and Parker 1992). Widespread deforestation and conversion of land to agriculture occurred in North America following European settlement, and as agriculture advanced to the northwest the number of wolves declined severely due to habitat destruction, fur harvests, reductions in the numbers of ungulate prey, and extermination by humans through predator control programs (Young and Goldman 1944; Nowak 2002). The gray wolf was extirpated from southeastern Ontario between 1850 and 1900 (Kolenosky and Standfield 1975), and soon after eastern wolves extended their range northward, apparently following the northward range expansion of white-tailed deer (Kolenosky and Standfield 1975; Nowak 2002 & 2003). Declines in the number of wolves coupled with the ability of coyotes to persist in agricultural areas and colonize disturbed habitat allowed coyotes to expand their range into southeastern Canada in the early 1900s (Nowak 1979).

Habitat and landscape conditions have been implicated in the reduction of the range of wolves and the expansion of the coyote's range northward in eastern North America (Nowak 1978; Moore and Parker 1992), as well as extensive hybridization between eastern wolves and coyotes in northeastern North America (Lehman *et al.* 1991; Wayne *et al.* 1992; Roy *et al.* 1994; Wilson *et al.* 2008). The movement of coyotes into northeastern North America in the early 1900s was followed by hybridization between coyotes and eastern wolves (Silver and Silver 1969; Kolenosky and Standfield 1975). Extensive hybridization between *C. lycaon* and *C. latrans* in northeastern North America has led to a hybrid species referred to as the "Tweed wolf" or eastern coyote (*Canis latrans X lycaon*) (Kolenosky and Standfield 1975; Sears *et al.* 2003; Wilson *et al.* 2008), which includes individuals that are morphologically and phenotypically intermediate between *C. lycaon* and *C. latrans*, and contain differing proportions of those species' genetic material. Hybridization between eastern wolves and coyotes appeared to involve asymmetric breeding (Lehman *et al.* 1991), whereby male wolves bred with female coyotes (Pilgrim *et al.* 1998). However, extensive and ongoing hybridization has obscured sex-biased mating between wolves and coyotes because of backcrossing of hybrid progeny, which has led to putative hybrid swarms (e.g. Wilson *et al.* 2008). No direct hybridization has been observed between gray wolves and coyotes in western populations (Pilgrim *et al.* 1998; Hailer and Leonard 2008), nor has direct hybridization been observed between Mexican gray wolves and coyotes (Garcia-Moreno *et al.* 1996; Hedrick *et al.* 1997; Hailer and Leonard 2008). The ability of eastern wolves to hybridize with coyotes is likely the result of their close evolutionary relationship (Wilson *et al.* 2000) whereas the more distantly related gray wolves do not breed with coyotes, however, there is evidence that eastern wolves and gray wolves hybridize (Mech and Federoff 2002; Wilson *et al.* 2008).

It is suggested that prior to European settlement the eastern wolf was separated from gray wolves and coyotes by glacial barriers (Nowak 2002) that were subsequently maintained by reproductive barriers due to habitat and prey specificities of the three species (Kolenosky and Standfield 1975; Moore and Parker 1992; Nowak 1995; Geffen *et al.* 2004). Agricultural and forestry practices along with predator control programs are suggested to have resulted in the breakdown of reproductive barriers between gray wolves and eastern wolves and between coyotes and eastern wolves in the northwestern and southeastern portions of the eastern wolf's range, respectively (Kyle *et al.* 2006). Putatively, this has led to what we know today as the "eastern wolf" being composed of individuals exhibiting a gradient of morphology and genetic composition across its range, with more coyote genetic material being observed in the southeastern portion of its range, and more gray wolf genetic material observed in the northwestern portion of its range (Kyle *et al.* 2006). The eastern wolf may be viewed as the mediator of hybridization among *Canis* species in North America, and this is supported by the lack of hybridization in western *Canis* populations where *C. lycaon* is absent (e.g. Pilgrim *et al.* 1998).

Wolves are highly mobile and capable of dispersing long distances (Fritts 1983; Mech 1987), and their ability to traverse many landscapes and potential topographic barriers (e.g. rivers, mountains) minimizes the influence of geographical factors on gene flow and masks the effects of historical events, making the effects of contemporary ecological factors on genetic differentiation more prominent (Pilot *et al.* 2006). However, when studying the distribution of *Canis* species, it is important to consider the historical broad scale patterns of colonization that have contributed to the present distributions of pure and hybrid *Canis* species. The present distribution of *Canis* reflects a combination of contemporary selective forces and historic colonization patterns, as well as recent colonization events and human factors such as landscape changes and wolf control programs. Ecological barriers to dispersal can also be important in shaping the distribution of *Canis* (e.g. Carmichael *et al.* 2001; Musiani *et al.* 2007).

Molecular Genetic Techniques for Studying Canis

The majority of early genetic studies of *Canis* were based on analyses of the mitochondrial DNA (mtDNA) control region, which is inherited maternally and clonally (i.e. lack of recombination) in mammals, and therefore can be used to detect past hybridization events (Pilgrim *et al.* 1998). Genotyping of microsatellite loci has led to a better understanding of the evolutionary relationships and hybridization patterns of *Canis* species, and has allowed for greater genetic differentiation at the level of the population and the individual (Roy *et al.* 1994; Wilson *et al.* 2000). Because of the high degree of polymorphism and evolutionary rate of microsatellite loci, they are very informative for describing gene flow and hybridization (Roy *et al.* 1994, Wilson *et al.* 2008). Analysis of the Y-chromosome in male *Canis* individuals can provide information on paternal gene flow, complementing mtDNA data to detect asymmetric breeding between species and determine the role of each sex in natural processes (Sundqvist *et al.* 2001). The combined information from these three types of genetic markers can achieve increased resolution in differentiating among populations or individuals, and facilitates a greater ability to describe and quantify the degree of admixture between species, as well as the directionality and temporal context of hybridization.

Objective of Thesis

Amidst the controversy over North American *Canis* taxonomy, the situation in the western Great Lakes region (WGLR) warrants special attention. Due to killing by humans and reductions in prey abundance, wolf populations were extirpated from Wisconsin and Michigan by 1960, and were eliminated from most of Minnesota, persisting only in the remote northeastern portion of the state (FWS 2007). At the same time wolves persisted across most of northern Ontario owing to the relatively vast expanses of uninhabited lands in this province. Since gaining protection under the Endangered Species Act in 1974, wolf populations in the western Great Lakes states have recovered to substantial enough numbers to facilitate the recent decision to de-list wolves as endangered/threatened in the Western Great Lakes Distinct Population Segment (FWS 2007). However, the taxonomic status and genetic identity of the current WGLR wolf population is uncertain, with some studies suggesting the animals are hybrids of gray wolves and coyotes (e.g. Lehman *et al.* 1991; Roy *et al.* 1994), and others suggesting that hybrids of eastern wolves and gray wolves may occur in the region (e.g. Mech and Federoff 2002; Wilson *et al.* 2008). The question of whether the recovered WGLR wolf population is representative of the historic (i.e. pre-recovery) population has been raised (Leonard and Wayne 2008), thereby casting doubt on the decision to de-list. With the genetic status of WGLR wolves uncertain in the face of changing conservation and management plans, a focused and detailed genetic study of these animals is necessary.

The overall objective of this thesis is to comprehensively determine the genetic composition of wolves from the WGLR using data from nuclear microsatellite loci, and mtDNA and Y-chromosome sequences. This study aims to clarify the debate over the identity of these canids and to provide further insight into the complex dynamics of *Canis* populations in northeastern North America. The findings of this research will likely have important implications for the conservation and management of *Canis* populations in Ontario and the western Great Lakes states, and broader implications relating to wolf taxonomy in North America.

The major goals of this thesis are: 1) to genetically characterize the animals that comprise the extant WGLR *Canis* population(s) and assess their relationship to populations from surrounding regions; 2) to genetically characterize wolves from the pre-recovery (i.e. historic) WGLR population and compare them to the extant population to determine if the historic population has been restored; and 3) to further assess the range of eastern wolf genetic material in North America.

Based on current knowledge gained from a combination of morphological and genetic studies of *Canis*, it was predicted that 1) wolf populations in the WGLR have not, and do not currently, hybridize with coyotes and 2) the eastern wolf has hybridized with both gray wolves and coyotes, and exhibits a genetic gradient across the landscape. The two central hypotheses of this thesis are that 1) gray wolves and coyotes do not hybridize in wild populations and 2) the eastern wolf is the mediator of *Canis* hybridization in northeastern North America.

This thesis is organized as follows: Chapter two assesses the genetic composition of the extant WGLR population(s) in relation to animals from surrounding regions; Chapter three assesses the genetic composition of historic animals from the WGLR and compares them to extant animals; and Chapter four presents a general discussion to summarize the findings of this thesis and provide a cohesive interpretation of the relations among *Canis* populations in northeastern North America. Recommendations for the conservation and management of *Canis* in northeastern North America are provided based on the findings of this thesis.

Chapter 2: Genetic characterization of contemporary *Canis* populations in the western Great Lakes region using multiple genetic markers

Abstract

The genetic status of *Canis* populations in northeastern North America has been debated for years, and has recently become more important to the conservation of wolves given their recent de-listing in the United States. The genetic composition of *Canis* in the western Great Lakes region (WGLR) and surrounding areas in northeastern North America was examined to determine which *Canis* species contributed to the genomes of extant wolves in the WGLR. Individual genotypes obtained from 12 microsatellite loci were analyzed, and revealed that the majority of the WGLR canids sampled are part of a large homogenous wolf population extending across Michigan, Wisconsin, Minnesota and northwestern Ontario. Mitochondrial DNA and Y-intron sequences were analyzed to determine the maternal and paternal genetic contributions to the current WGLR wolf population, and revealed predominantly eastern wolf and gray wolf ancestry in WGLR canids, with animals having coyote ancestry being distinct from wolves. Thus, based on the three genetic markers used in this study, the WGLR wolf population was determined to be composed of gray-eastern wolf hybrids that do not breed with sympatric coyotes.

Introduction

In northeastern North America, extensive hybridization between *Canis* species has led to a gradient of genetic and morphological differences throughout the landscape (e.g. Kolenosky and Standfield 1975; Wayne and Vila 2003). There has been longstanding debate concerning the taxonomic status of canids in this region, with previous designations being largely based on morphological differences and variation in phenotypic traits (Miller 1912; Pocock 1935; Goldman 1944; Nowak 1979). It is generally accepted that the progenitor of the gray wolf (*Canis lupus*) migrated from North America to Eurasia and evolved there approximately 1 to 2 million years ago, and later returned via the Bering land bridge (Nowak 1979; Lehman *et al.* 1991; Wilson *et al.* 2000). Based on genetic evidence the eastern wolf (*C. lycaon*) was shown to be a distinct species, conspecific to the red wolf (*C. rufus*), that evolved in North America sharing a common lineage with the western coyote (*C. latrans*) until 150 000 to 300 000 years ago (Wilson *et al.* 2000). The different evolutionary history of these *Canis* species is reflected in their mitochondrial genomes: gray wolves have Old World evolved sequences, and eastern/red wolves and coyotes have New World evolved sequences.

Movement of coyotes into eastern North America in the early 1900s was followed by hybridization between coyotes and eastern wolves (Silver and Silver 1969; Kolenosky and Standfield 1975), which has been extensive and led to the eastern coyote (*Canis latrans X lycaon*) (e.g. Wilson *et al.* 2008). In contrast, no direct hybridization has been observed between gray wolves and coyotes in western populations (e.g. Pilgrim *et al.* 1998; Hailer and Leonard 2008). The ability of eastern wolves to hybridize with coyotes is likely the result of their close evolutionary relationship (Wilson *et al.* 2000), yet there is also evidence that eastern wolves and gray wolves hybridize (Mech and Federoff 2002; Wilson *et al.* 2008). Agricultural and forestry practices along with predator control programs seem to have broken down reproductive barriers between *Canis* species and led to hybridization between coyotes and eastern wolves, and between gray wolves and eastern wolves (Kyle *et al.* 2006). Accordingly, the eastern wolf currently exhibits a gradient of morphology and genetic composition across its range, with more coyote genetic material observed in the southeastern portion of its range, and more gray wolf genetic material observed in the northwestern portion of its range (Kyle *et al.* 2006). The eastern wolf may be viewed as the mediator of hybridization among *Canis* species in North America, and this is supported by the lack of hybridization in western *Canis* populations where *C. lycaon* is absent (Pilgrim *et al.* 1998). Yet, despite elucidating these patterns of hybridization, considerable uncertainty exists regarding the genetic identity of canids in northeastern North America and the relationships among populations, stressing the importance of genetic research on canids in this region.

The canids of the western Great Lakes region warrant special attention given that by 1960 wolf populations were extirpated from Wisconsin and Michigan, and were eliminated from most of Minnesota (FWS 2007). Wolves have since recovered in the region and were recently removed from protection under the Endangered Species Act in the U.S. (FWS 2007). However, the taxonomic status and genetic identity of the current wolf population is uncertain, with studies suggesting that these canids are either hybrids of gray wolves and coyotes (e.g. Lehman *et al.* 1991; Roy *et al.* 1994; Leonard and Wayne 2008) or hybrids of eastern wolves and gray wolves (e.g. Mech and Federoff 2002; Wilson *et al.* 2008). Given the uncertain taxonomic status of wolves in the western Great Lakes region, a focused and detailed genetic study of these animals was necessary to facilitate effective conservation and management.

The goal of this study was to characterize the genetic attributes of *Canis* in the western Great Lakes region. This investigation is critical because it will elucidate the genetic makeup and attendant conservation status of canids in this region. This understanding is particularly relevant given the recent de-listing of wolves in the area and the fact that their genetic status may be paramount to the outcome of impending legal battles between animal's rights groups and government agencies.

Materials & Methods

Samples and DNA Extraction

Samples from 404 canids (i.e. wolves and coyotes) were collected from across northern Ontario and the western Great Lakes states: northwestern Ontario, n = 92; northeastern Ontario, n = 97; Michigan, n = 114; Wisconsin, n = 48; Minnesota, n = 53. For this study these sampling locations collectively represent the western Great Lakes region (WGLR). These samples included whole tissue (n = 326), blood on FTA cards (n = 68), scat swabs (n = 8) and hairs (n = 2). DNA was extracted from samples using a DNeasy Blood and Tissue Kit (Qiagen Inc., Mississauga, ON). A Picogreen assay was used to quantify the concentration of DNA obtained from extraction for each sample.

Gender Determination

The following consensus primers were used to amplify 931 and 1087 base pair (bp) fragments of the X-chromosome and Y-chromosome respectively (Cathey *et al.* 1998).

LGL-331 5'-CAA ATC ATG CAA GGA TAG AC-3'

LGL-335 5'-AGA CCT GAT TCC AGA CAG TAC CA-3'

The Zfx/Zfy sexing fragments were amplified in a total reaction volume of 10-20 µl per tube using 5 ng of genomic DNA, 200 µM dNTPs, 1x amplification buffer, 1.5 mM $MgCl_2$, 0.2 µM of primers LGL-331 and LGL-335, and 0.04 units of Taq polymerase (BRL). For blood, scat and hair samples 0.1 µg/µL of BSA was included in the reaction.

Products were amplified under the following conditions: 94°C for 5 min, 55°C for 30 sec, 72°C for 30 sec; 94°C for 30 sec, 55°C for 30 sec, 72°C for 30 sec, 30 cycles; 94°C for 30 sec, 55°C for 30 sec, 72°C for 10 min.

The following primer pairs were used to amplify 445 and 224 bp fragments of the X-chromosome (P2-3EZ and P1-5EZ: Aasen and Medrano 1990) and Y-chromosome (Y53-3C and Y53-3D: Fain and LeMay 1995) respectively.

P2-3EZ	5'-GCA CTT CTT TGG TAT CTG AGA AAG T-3'
P1-5EZ	5'-ATA ATC ACA TGG AGA GCC ACA AGC T-3'
Y53-3C	5'-CCC ATG AAC GCA TTC ATT GTG TGG-3'
Y53-3D	5'-ATT TTA GCC TTC CGA CGA GGT CGA TA-3'

The Zfx/Sry sexing fragments were amplified in a total reaction volume of 10-20 µl per tube using 5 ng of genomic DNA, 200 µM dNTPs, 1x amplification buffer, 2.5 mM $MgCl_2$, 0.2 µM of each primer, and 0.05 units of Taq polymerase (BRL). For blood, scat and hair samples 0.15 µg/µL of BSA was included in the reaction. Products were amplified under the following conditions: 95 for 1 min; 94 for 45 sec, 58 for 45 sec, 73 for 1 min, 35 cycles; 72 for 2 min.

The Zfx/Zfy primers were used for gender determination of scat samples because the Zfx/Sry primers can amplify non-target mammalian DNA that includes prey species of canids. The Zfx/Sry primers were used for gender determination of the tissue, blood and hair samples. For both primer sets the variation in fragment size between the X-chromosome and Y-chromosome results in males generating two bands of variable size and females generating two bands of equal size. Gender was determined for samples by visualization of banding patterns of amplified Zfx/Zfy or Zfx/Sry products on an ethidium bromide stained agarose gel.

Mitochondrial DNA Control Region Sequencing

The following primers were used to amplify a 343-347 bp fragment of the control region of the mitochondrial DNA.

AB13279 5'-GAA GCT CTT GCT CCA CCA TC-3' (Pilgrim *et al.* 1998)

AB13280 5'-GGG CCC GGA GCG AGA AGA GGG AC-3' (Wilson *et al.* 2000)

The control region was amplified in a total reaction volume of 20 µl per tube using 5 ng of genomic DNA, 200 µM dNTPs, 1x amplification buffer, 1.5 mM $MgCl_2$, 0.2 µM of primers AB13279 and AB13280, and 0.05 units of Taq polymerase (BRL). For blood, scat and hair samples 0.1 µg/µL of BSA was included in the reaction. Products were amplified under the following conditions: 94°C for 5 min, 60°C for 30 sec, 72°C for 30 sec; 94°C for 30 sec, 60°C for 30 sec, 72°C for 30 sec, 30 cycles; 94°C for 30 sec, 60°C for 30 sec, 72°C for 2 min. PCR products were cleaned using Exosap-IT (USB Corporation, Cleveland, OH) prior to sequencing on a MegaBACE 1000 (GE Healthcare).

Y-intron sequencing

The following Zfx/Zfy intron specific primers were used to amplify a 658 bp fragment of the final intron of the Zfy gene (Y-chromosome).

LGL-331 5'-CAA ATC ATG CAA GGA TAG AC-3' (Cathey *et al.* 1998)

Yint2-335 5'-GTC CAT TGG ATA ATT CTT TCC-3' (Shami 2002)

The Y-intron was amplified in a total reaction volume of 20 ul per tube using 5 ng of genomic DNA, 200 uM dNTPs, 1x amplification buffer, 1.5 mM $MgCl_2$, 0.2 μM of primers LGL-331 and Yint2-335, 0.1 μg/μL of BSA and 0.05 units of Taq polymerase (BRL). Products were amplified under the following conditions: 94°C for 5 min, 52°C for 30 sec, 72°C for 30 sec; 94°C for 30 sec, 52°C for 30 sec, 72°C for 30 sec, 35 cycles; 94°C for 30 sec, 52°C for 30 sec, 72°C for 10 min. PCR products were cleaned using Exosap-IT (USB Corporation, Cleveland, OH) prior to sequencing on a MegaBACE 1000 (GE Healthcare).

Microsatellite Genotyping

Amplification of twelve microsatellite loci was attempted for each sample (Ostrander *et al.* 1993 and 1995: cxx225, cxx200, cxx123, cxx377, cxx250, cxx204, cxx172, cxx109, cxx253, cxx442, cxx410, cxx147) in a total reaction volume of 15μl per tube using 5 ng of genomic DNA, 200 μM dNTPs, 1x amplification buffer, 1.5 mM $MgCl_2$, 0.2-0.3 μM of forward (labeled with fluorescent dye: 6FAM, NED or HEX) and reverse (unlabeled) primer, and 0.05 units of Taq polymerase (BRL). For blood, scat and hair samples 0.1-0.15 μg/μL of BSA was included in the reaction. Products were amplified under the following conditions: 94°C for 5 min; 94°C for 30 s, 56-58°C for 1 min, 72°C for 1 min, 30 cycles; 60°C for 45 min. PCR products were purified through ethanol precipitation prior to genotyping on a MegaBACE 1000 (GE Healthcare).

Genetic analysis

Mitochondrial DNA sequences were edited in Bioedit (Hall 1999) and assigned haplotypes, denoted as C(X), corresponding to the haplotypes described by Wilson *et al.* (2000 & 2003). Sequences were aligned using ClustalW multiple alignment in Bioedit, and then manually edited to achieve the best alignment, minimizing the number of variable sites (i.e. substitutions and gaps). The program MODELGENERATOR (Keane *et al.* 2006) was used to determine the most appropriate model of substitution for generating a phylogenetic tree. Based on the chosen alignment, the HKY model of substitution with a discrete gamma model of rate heterogeneity (alpha = 0.18) was selected as the most appropriate model for the data. The nucleotide base frequencies determined by MODELGENERATOR for the sequences were as follows: A = 0.27506, T = 0.30605, C = 0.28650, G = 0.13239. No transversions were observed among the sequences based on the chosen alignment.

A neighbor-joining tree was constructed using NEIGHBOR in PHYLIP (Felsenstein 2005), assuming a transition/transversion ratio of 15.47 (Vila *et al.* 1999), and using a HKY model with a gamma distribution (alpha = 0.18). A neighbor-joining tree was also constructed in MEGA version 4.0 (Tamura *et al.* 2007) using the Maximum Composite Likelihood (MCL) method with a gamma distribution (alpha = 0.18). The HKY model is not available in MEGA, however the MCL method is implemented under the Tamura-Nei substitution model in MEGA (Tamura *et al.* 2007), which was the fifth best model selected by MODELGENERATOR; therefore the MCL method was a suitable replacement for the HKY model. Tamura-Nei genetic distances have been used previously for analyses of canid mtDNA control region sequences (Andersone *et al.*

2002). A maximum parsimony tree was constructed using MEGA, including all sites and implementing a close-neighbor interchange with search level 3. For all trees support for branches was assessed based on 1000 bootstrap replicates and consensus trees were generated, rooted with a Golden Jackal sequence (C*anis aureus*, Genbank accession # AY289996). Both neighbor-joining trees and the maximum parsimony tree produced similar topologies.

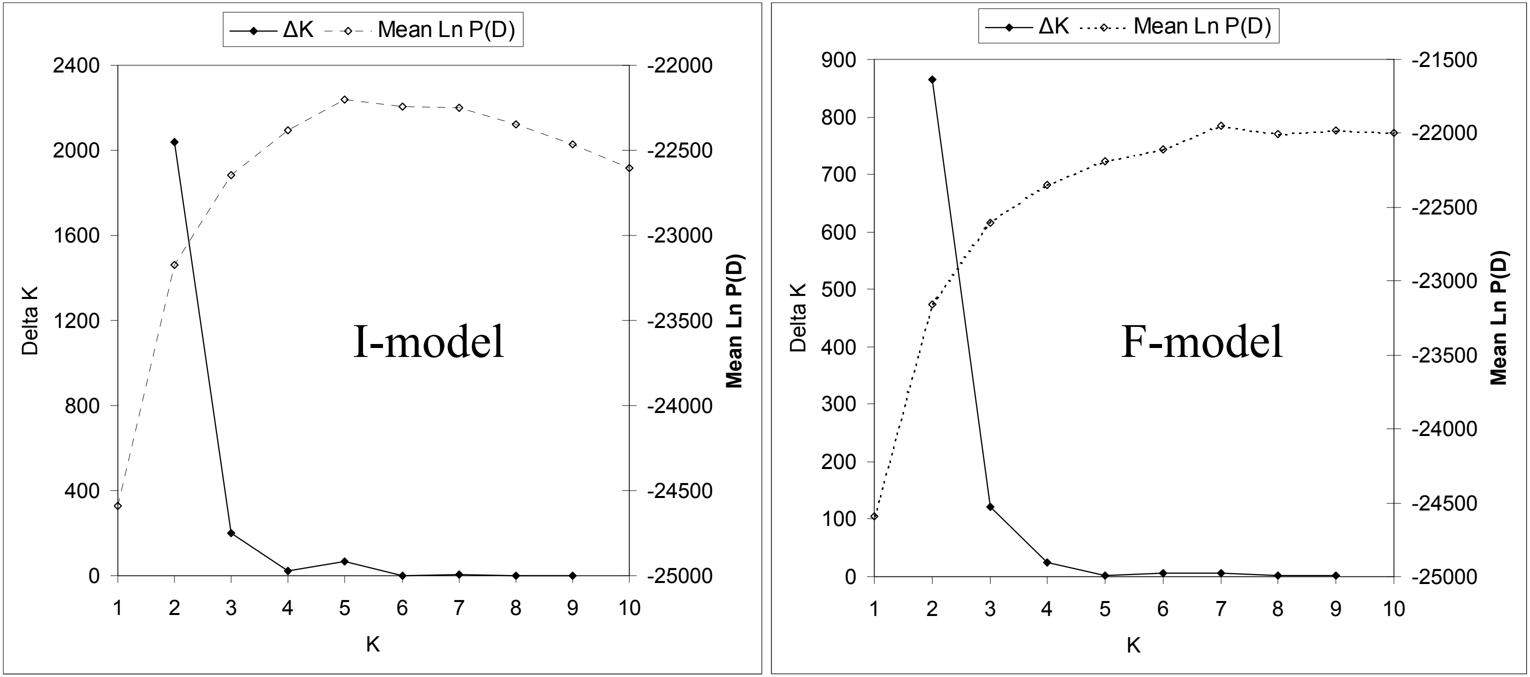
Overall sequence diversity and the mean pair-wise sequence divergence within groups and between groups was calculated using the MCL method in MEGA with a gamma distribution (alpha = 0.18) and obtaining estimates of standard error from 1000 bootstrap replicates. Sequence comparisons incorporated pair-wise deletions, and the Golden Jackal sequence was omitted for the diversity and mean pair-wise sequence divergence calculations.

Y-intron sequences were edited and aligned in Bioedit (Hall 1999), and assigned haplotypes to correspond with the work of Shami (2002): CANInt1 = ancestral haplotype; CANInt2 = gray wolf haplotype; CANInt4 = eastern wolf haplotype.

Microsatellite alleles were scored in Genemarker (v1.7, SoftGenetics LLC, State College, PA) and unique genotypes were obtained for 371 samples: northwestern Ontario, n = 87; northeastern Ontario, n = 93; Michigan, n = 90; Wisconsin, n = 48; Minnesota, n = 53. Of the 371 genotyped individuals only eight samples were from low template DNA sources (i.e. scat or hair), thus genotyping error was assumed to be negligible overall since the samples consisted almost entirely of high template DNA sources (i.e. tissue and blood), reducing the likelihood of scoring errors due to allelic dropout. Homozygous allele scores were confirmed for two of the low template samples, and five of the remaining low template samples for which homozygous alleles scores were not confirmed had heterozygous allele scores at eight or more of the twelve loci amplified, further reducing the potential for scoring errors due to allelic dropout. Additional samples (n = 256) from a previous study by Grewal (2001) were genotyped at the same twelve loci for inclusion in the genetic analyses to observe how the WGLR samples relate to canids from surrounding areas: 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); Quebec, n = 34 (western Quebec, n = 24; eastern Quebec, n = 10); Algonquin Provincial Park, n = 54 (L. Rutledge, unpublished data); Frontenac Axis, n = 52; Texas, n = 24.

The microsatellite genotype data from these 627 canids was analyzed using STRUCTURE (v2.2, Pritchard *et al.* 2000; Falush *et al.* 2003, 2007), which uses a Bayesian approach to infer the number of populations and estimates admixture proportions by assigning each multilocus genotype a probability of membership in each genetic cluster. The admixture model of STRUCTURE was run for K = 1 to K = 10 with five repetitions of 10^6 iterations following a burn-in period of 250,000 iterations for each K. The I-model (i.e. assumes independent allele frequencies among populations) and the F-model (i.e. allows for correlated allele frequencies among populations) were both implemented to compare results. For both models a separate alpha was inferred for each population to account for asymmetric admixture. The posterior probability (Ln P[D]) for a given K was computed by averaging the posterior probabilities across the five runs for that K. Based on a combination of criteria from Pritchard *et al.* (2000; maximal value of Ln P[D]) and Evanno *et al.* (2003; ΔK), and considering the overall individual ancestry assignments and biological significance, the number of populations K was determined to be five for the I-model and seven for the F-model (Figure 2.1). The large ΔK value observed at K = 2 for both models likely reflects the hierarchical splitting of wolf-like from coyote-like canids (see Discussion), whereas the ΔK peak at K = 5 for the I-model (Figure 2.1) likely reflects the highest level of population subdivision, which is supported by the maximal value of Ln P(D) and high ancestry assignments of individuals to specific populations at K = 5. The determination of K for the F-model was less clear based on ΔK (Figure 2.1), however the maximal value of Ln P(D) at K = 7 and the high ancestry assignments of individuals to the two additional populations inferred by the F-model, relative to the I-model, support the population structure observed at K = 7 (see Discussion for additional interpretation of difference in K between models). For both models the data was run through STRUCTURE again for the selected value of K with ten repetitions and the individual admixture proportions (i.e. Q-values) were taken from the run having the highest posterior probability and lowest variance.

Tests of the assumptions inherent to STRUCTURE, i.e. Hardy-Weinberg equilibrium (HWE) and linkage equilibrium (LE), were performed on the original geographic groups of samples, and on the groups of individuals highly assigned (Q>0.8) to the $K_I = 5$ and $K_F = 7$ populations inferred in STRUCTURE for the I-model and F-model respectively. Deviations from HWE were tested for all locus-population combinations and globally with an exact Hardy-Weinberg test using the Markov chain method (Guo and Thompson 1992) implemented in GENEPOP 4.0 (Rousset 2008). GENEPOP was also used to test pairwise LE among loci overall and within populations. The significance levels for HWE and LE tests were adjusted using the sequential



	K	1	2	3	4	5	6	7	8	9	10
I-model	ΔK	N/A	2040.24	198.27	21.46	67.05	1.93	5.36	1.76	0.29	N/A
I-model	Mean Ln P(D)	-24589	-23172	-22645	-22384	-22204	-22240	-22248	-22346	-22464	-22605
F-model	ΔK	N/A	864.45	120.69	24.31	2.59	5.47	6.38	1.69	1.16	N/A
F-model	Mean Ln P(D)	-24588	-23161	-22604	-22350	-22187	-22111	-21946	-22006	-21982	-22000

Figure 2.1: Plots of K determination criteria values, ΔK and Ln P(D), for the I-model and F-model of STRUCTURE. Highlighted values indicate the maximal value of Ln P(D) for each model.

Bonferroni method to account for multiple tests on the same data (Rice 1989). Pairwise estimates of F_{ST} (Weir and Cockerham 1984) were computed in GENEPOP for all populations inferred by STRUCTURE (individuals with Q>0.8) for $K_I = 5$ and $K_F = 7$.

To supplement the results from STRUCTURE, a non-model based Factorial Correspondence Analysis (FCA) was performed on the microsatellite data for individual canids using GENETIX (v4.05, Belkhir *et al.* 2004). Two factorial components FC-1 and FC-2, which accounted for 5.75% and 3.23% of the total inertia respectively, were plotted to visualize the relative clustering of animals from the different sampling locations.

Results

Mitochondrial DNA haplotypes

A 223-229 bp (note C98 = 200 bp) informative region of the mtDNA control region was sequenced for 404 samples, and a previously identified diagnostic insertion/deletion was used to distinguish between Old World (OW) and New World (NW) mtDNA sequences (Pilgrim *et al.* 1998). Eighteen mtDNA haplotypes were observed in the study region: 13 were of NW origin (n = 260) and 5 were of OW origin (n = 144) (Table 2.1).

Phylogenetic analysis of mtDNA sequences revealed three haplotype groupings similar to those observed by Wilson *et al.* (2000 & 2003), corresponding to gray wolves, eastern wolves and coyotes (Figure 2.2). Overall sequence diversity was 0.118 ±0.044 (S.E.), and average pair-wise sequence divergence within groups was 2.0 ±0.8% (range 0.5─3.3%) for gray wolves, 1.5 ±0.8% for eastern wolves, and 2.4 ±0.9% (range 0.5─5.7%) for coyotes. Average pair-wise sequence divergence between groups was

Table 2.1: Mitochondrial DNA and Y-intron haplotype frequencies of canid samples. Location(s) mtDNA haplotypes were observed in: MN = Minnesota; WI = Wisconsin; MI = Michigan; NWON = northwestern Ontario; NEON = northeastern Ontario; WGLR = western Great Lakes region (includes all locations listed here).

Mitochondrial DNA			Sex			Y-intron Haplotypes			Location(s) observed
Haplotype	OW/NW	Frequency	Female	Male	Unknown	CANInt1	CANInt2	CANInt4	
C1	NW	3	2	1	.	.	.	.	MI, NEON
C3	NW	70	32	34	4	.	10	22	entire WGLR
C5	NW	1	.	1	.	1	.	.	WI
C9	NW	16	5	10	1	3	4	3	entire WGLR
C13	NW	121	46	64	11	.	30	25	entire WGLR
C14	NW	24	8	16	.	1	12	2	MI, NEON
C17	NW	2	1	1	.	.	1	.	NEON
C19	NW	13	3	8	2	5	1	2	MN, WI, MI, NEON
C48	NW	1	1	.	.	.	.	.	WI
C70	NW	1	1	.	.	.	.	.	MN
C72	NW	1	1	.	.	.	.	.	MN
C98	NW	3	1	2	.	2	.	.	NWON
C99	NW	4	1	2	1	1	.	.	NWON, NEON
C22	OW	114	48	57	9	.	37	16	entire WGLR
C23	OW	19	8	9	2	.	7	2	MN, WI, NWON, NEON
C95	OW	2	1	1	.	.	1	.	NWON, NEON
C96	OW	1	.	1	.	.	1	.	MI
C97	OW	8	2	4	2	.	2	2	WI, MI
Total		404	161	211	32	13	106	74	

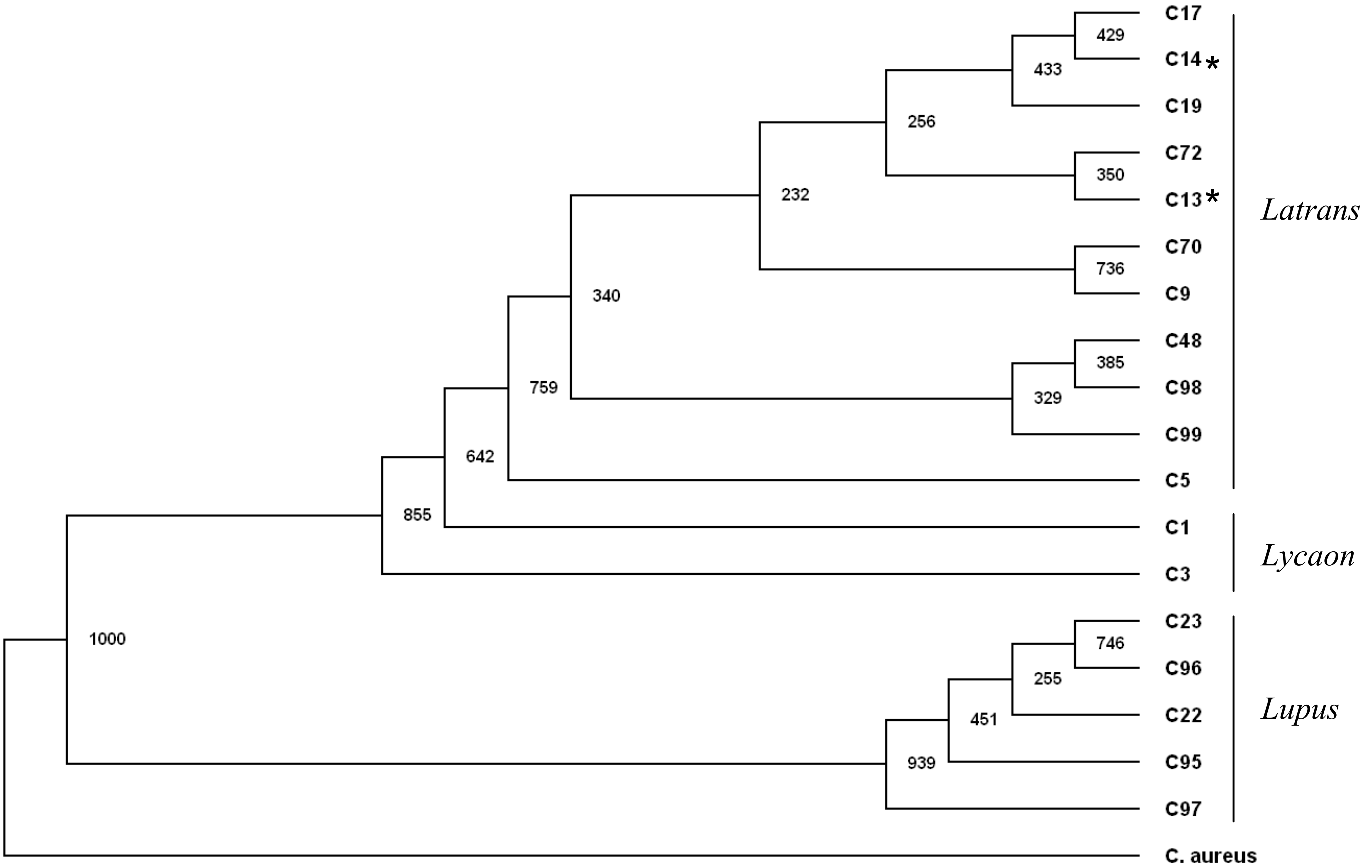


Figure 2.2: Neighbor-joining tree of canid mtDNA haplotypes generated using PHYLIP. Number at branch node indicates bootstrap support out of 1000. Asterisks (*) indicate *C. latrans* clustering sequences interpreted as being primarily derived from *C. lycaon* in the study region.

14.8 ±6.9% (range 13.2─16.6%) for gray wolves and eastern wolves, 25.4 ±11.7% (range 17.4─34.3%) for gray wolves and coyotes, and 4.7 ±1.9% (range 2.6─7.4%) for eastern wolves and coyotes.

The distribution of haplotypes showed extensive overlap of OW and NW haplotypes throughout the study region (Figure 2.3). The most prevalent haplotypes were C3 (n = 70), C13 (n = 121), and C22 (n = 114), which were collectively observed in ~75% of the animals sampled spanning the majority of the study region (Table 2.1, Figure 2.3). The other observed haplotypes occurred in lower frequency (i.e. n<25) across the study region, although haplotype C14 was the predominant NW haplotype in northeastern Ontario (Figure 2.3).

Y-intron haplotypes

Genetic determination of gender revealed 161 females and 211 males (Table 2.1), and gender was not successfully determined for the remaining 32 samples. Y-intron sequences were obtained for 91% of genetically identified male canids. A 463 bp fragment was sequenced that incorporated the variable sites identified by Shami (2002), from which three unique haplotypes were observed: ancestral, n = 13; gray wolf, n = 106; eastern wolf, n = 74 (Table 2.1). The gray wolf and eastern wolf Y-intron haplotypes were far more prevalent than the ancestral haplotype. The coyote Y-intron haplotype (i.e. CANInt3) observed by Shami (2002) was not observed in any animals in the study region. The distribution of Y-intron haplotypes in the study area showed extensive overlap of the eastern wolf and gray wolf Y-intron haplotypes (Figure 2.4). The gray wolf Y-intron haplotype was predominant in northeastern Ontario, however, the eastern wolf

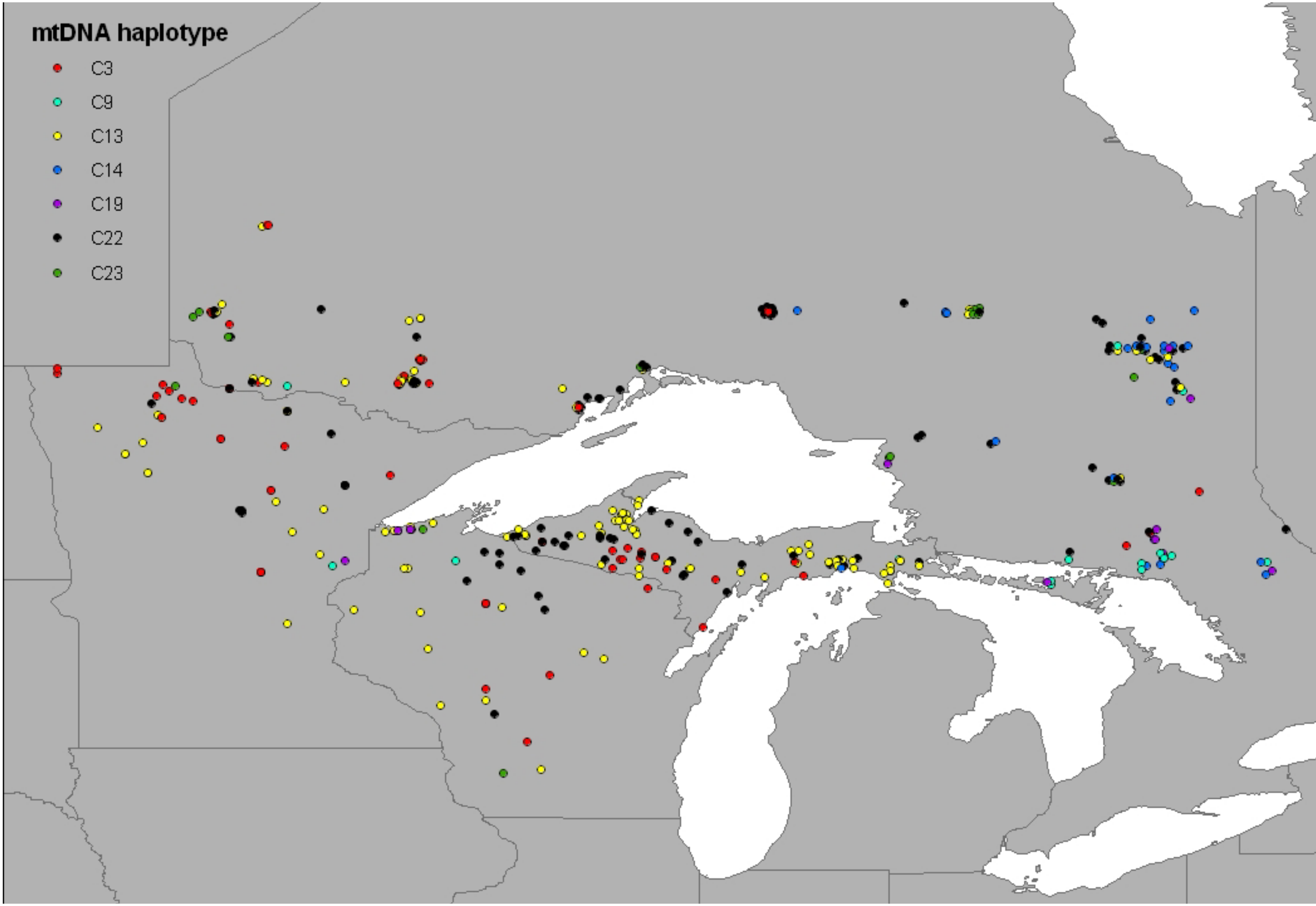


Figure 2.3: Geographic distribution of canid mtDNA haplotypes (n>10) in the western Great Lakes region.

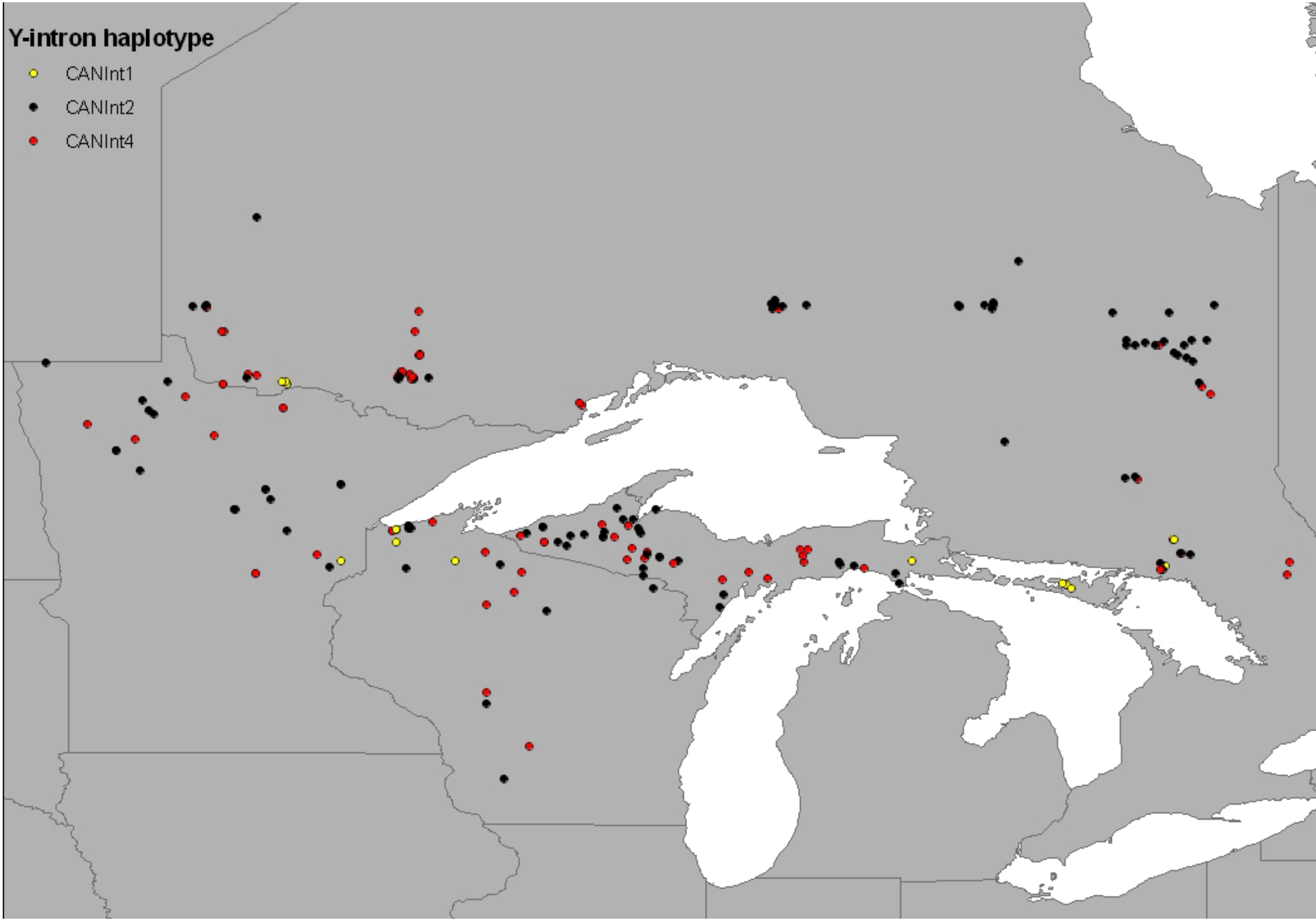


Figure 2.4: Geographic distribution of canid Y-intron haplotypes in the western Great Lakes region.

Y-intron haplotype was still present in this region (Figure 2.4). The ancestral Y-intron haplotype was not observed in the northern portions of the study region (Figure 2.4).

Microsatellite genotypes

The microsatellite loci had on average 9.5 ±3.4 (S.D.) alleles per locus (range 5 to 16). The geographic sample groups showed overall deviations from HWE at seven loci and deviations from LE for twelve pairs of loci. Several specific geographic sample groups showed deviations from HWE at one or more loci and deviations from LE for one or more pairs of loci. The populations inferred by STRUCTURE (individuals with $Q>0.8$) were in overall HWE for $K_I = 5$ and $K_F = 7$, and all loci for all populations were individually in HWE. The STRUCTURE inferred populations were in overall LE across all pairs of loci, however, for $K_I = 5$ three populations showed deviations from LE for one pair of loci each, and for $K_F = 7$ one population showed deviation from LE for one pair of loci. These results suggest that the deviations from HWE and LE present in the geographic sample groups were appropriately modeled by STRUCTURE to generate the genetically inferred populations, which conform to HWE and LE.

The I-model in STRUCTURE inferred five genetic populations (Figure 2.5): P_I1 = Texas; P_I2 = Frontenac Axis; P_I3 = Algonquin Park; P_I4 = Manitoba, Minnesota, Wisconsin, Michigan, northwestern/northeastern Ontario and Quebec; P_I5 = Northwest Territories. The F-model in STRUCTURE inferred seven genetic populations (Figure 2.5): P_F1 = Texas; P_F2 = Frontenac Axis; P_F3 = Algonquin Park; P_F4 = Minnesota, Wisconsin, Michigan and northwestern Ontario; P_F5 = northeastern Ontario and Quebec; P_F6 = Manitoba; P_F7 = Northwest Territories.

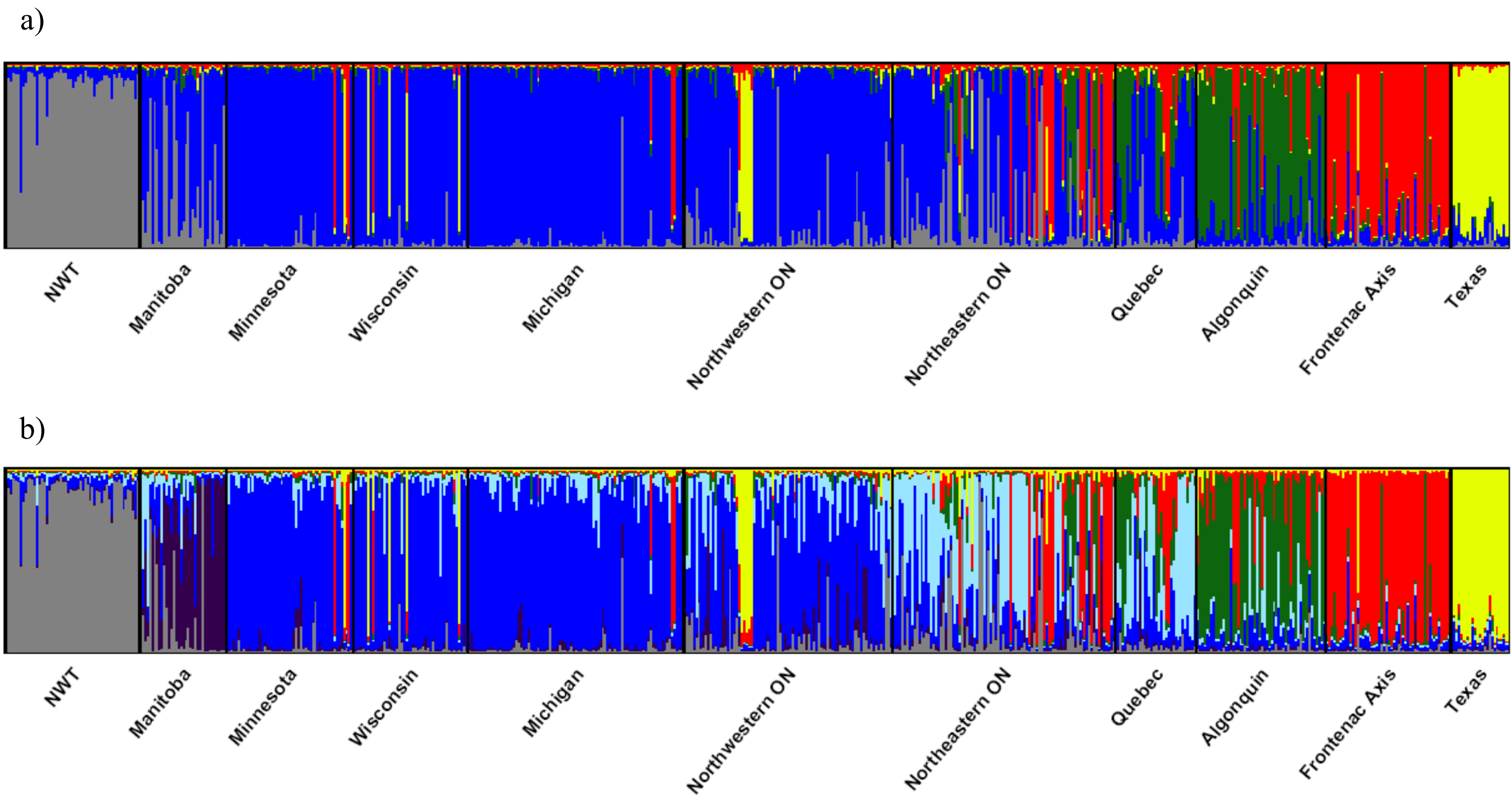


Figure 2.5: Plot of individual proportional memberships to the populations inferred by STRUCTURE under a) I-model (K = 5) and b) F-model (K = 7).

The difference in clustering between the I-model and F-model is that P_I4 inferred under the I-model splits into P_F4, P_F5 and P_F6 under the F-model. Multimodal probabilities were encountered for some values of K for both the I-model (at K = 4) and the F-model (at K = 4, K = 5 and K = 6), resulting in variable clustering of groups for a given value of K, i.e. certain groups sorted out alternatively between two sequential values of K. However the I-model was more stable than the F-model, and showed consistent clustering and individual ancestry assignments among runs at $K_I = 5$, the value for which support was strongest based on the criteria of Pritchard *et al.* (2000) and Evanno *et al.* (2003). The F-model showed more inconsistency in clustering of groups than the I-model, specifically in how groups sorted out between $K_F = 4$ and $K_F = 6$. Although, the F-model showed some variation in individual ancestry assignments among runs at $K_F = 7$, it consistently identified the presence of the P_F5 and P_F6 clusters, with both having notable numbers of highly assigned individuals. The highest posterior probability occurred at $K_F = 7$ under the F-model, suggesting that the population structure observed at $K_F = 7$ exists, but it is likely complex. The F-model is able to detect more subtle population structuring but may tend to overestimate K (Falush *et al.* 2003). Given that $K_I = 5$ was more stable than $K_F = 7$, and P_I4 included the extra two populations inferred under the F-model (P_F5 and P_F6), it was determined that $K_I = 5$ provided a more reliable and conservative broad taxonomic view of the population structure. Therefore, the $K_I = 5$ admixture proportions of individual canids were deemed appropriate for relating to the mtDNA and Y-intron haplotype content of the animals.

Pairwise F_{ST} values revealed the genetic differentiation between the populations inferred by STRUCTURE, indicating a relatively low genetic differentiation between P_I1

and P_I2 (same for P_F1 and P_F2), and a relatively large genetic differentiation between P_I1 and P_I5 (same for P_F1 and P_F7) (Table 2.2). Notably, there was relatively low genetic differentiation between P_F4 and P_F5 (Table 2.2).

The FCA revealed roughly five distinct clusters, represented by the Northwest Territories, Algonquin Park, Texas and Frontenac Axis sample groups, and one large cluster of the western Great Lakes states, northwestern/northeastern Ontario, Manitoba, and Quebec sample groups (Figure 2.6). The northeastern Ontario and Manitoba sample groups clustered notably closer to the Northwest Territories samples and showed some deviation from the core cluster of the western Great Lakes states and northwestern Ontario groups (Figure 2.6). Several individuals from the western Great Lakes states and northwestern Ontario sample groups were observed clustering relatively intermediate to the Frontenac Axis and Texas samples groups, and several individuals from northeastern Ontario were observed clustering closely with the Frontenac Axis samples (Figure 2.6).

Combined genetic data

The ancestral Y-intron haplotype was only observed in animals with a NW mtDNA haplotype (Table 2.1) and high assignment to either P_I1 or P_I2, with the exception of one animal that had a mixed assignment to P_I3 and P_I4. The gray wolf and eastern wolf Y-intron haplotypes occurred in highest frequency in animals having the C3, C13 or C22 mtDNA haplotype, and the gray wolf Y-intron haplotype was also observed in twelve animals with mtDNA haplotype C14 in northeastern Ontario (Table 2.1). The majority of animals having a coyote mtDNA haplotype (note that C13 and C14 are interpreted as

Table 2.2: Pairwise estimates of F_{ST} for groups of individuals highly assigned (Q>0.8) to the populations inferred by STRUCTURE under a) I-model (K = 5; P_In) and b) F-model (K = 7; P_Fn). Inferred populations: P_I1 & P_F1 = *C. latrans* (Texas); P_I2 & P_F2 = *C. latrans-lycaon* hybrids (Frontenac Axis); P_I3 & P_F3 = *C. lycaon* (Algonquin Park); P_I4 = *C. lupus-lycaon* hybrids (Manitoba, Minnesota, Wisconsin, Michigan, northwestern/northeastern Ontario and Quebec); P_I5 & P_F7 = *C. lupus* (Northwest Territories); P_F4 = *C. lupus-lycaon* hybrids (Minnesota, Wisconsin, Michigan and northwestern Ontario); P_F5 = *C. lupus-lycaon* hybrids (northeastern Ontario and Quebec); P_F6 = *C. lupus-lycaon* hybrids (Manitoba).

a)

Population	P_I1	P_I2	P_I3	P_I4
P_I2	0.077			
P_I3	0.173	0.103		
P_I4	0.156	0.147	0.118	
P_I5	0.196	0.191	0.215	0.123

b)

Population	P_F1	P_F2	P_F3	P_F4	P_F5	P_F6
P_F2	0.078					
P_F3	0.184	0.109				
P_F4	0.144	0.146	0.164			
P_F5	0.171	0.157	0.135	0.068		
P_F6	0.177	0.164	0.232	0.148	0.129	
P_F7	0.201	0.199	0.238	0.134	0.150	0.168

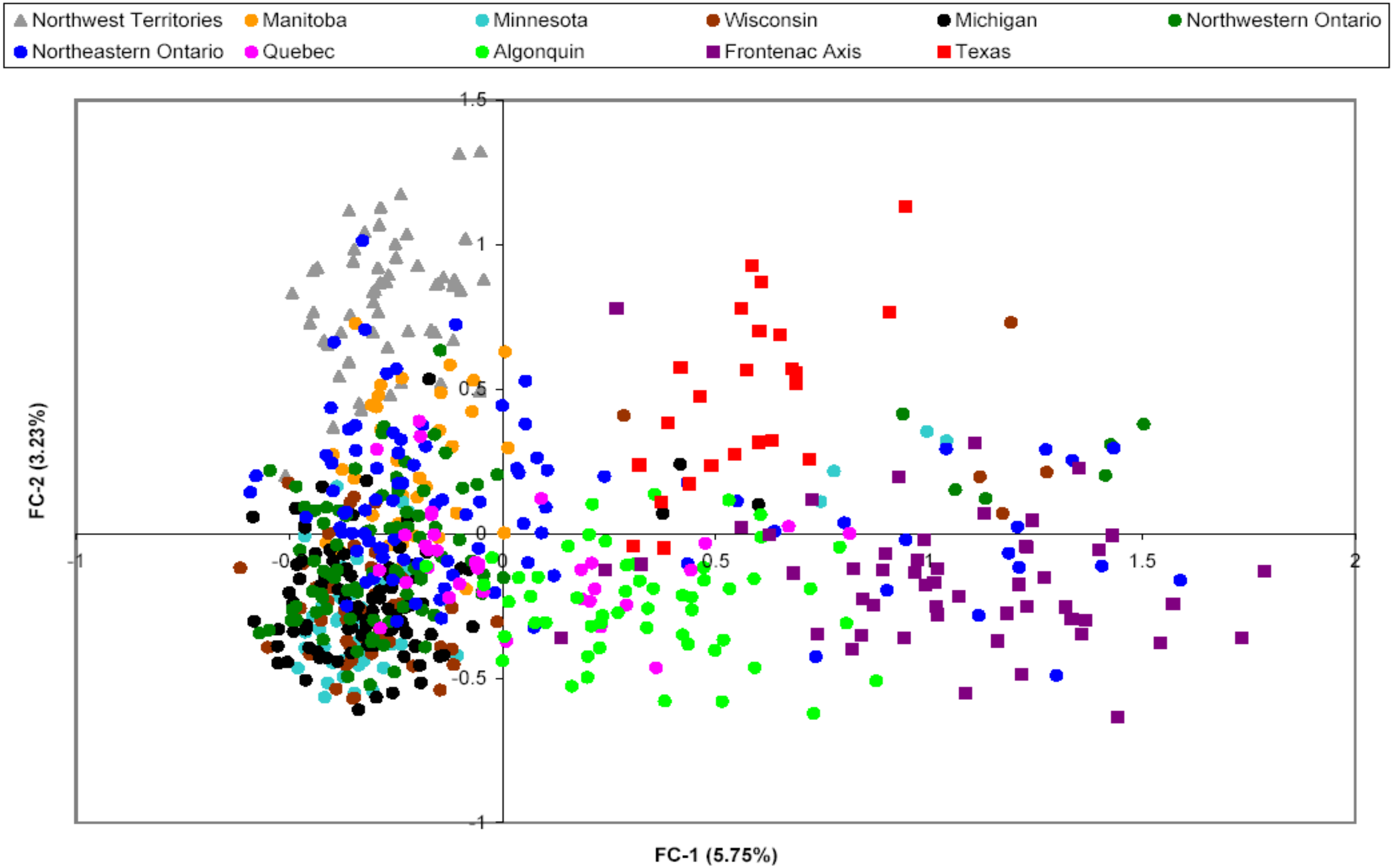


Figure 2.6: Factorial correspondence analysis of microsatellite loci for *Canis* sample groups. Symbol type of sample group indicates mtDNA haplotypes present: circle = Old World and New World; triangle = Old World; square = New World.

haplotypes derived primarily from *C. lycaon* in the study region, see Discussion) had high assignment to the P_I1 or P_I2 cluster, with the exception of haplotype C9, which despite occurring predominantly in animals with high assignment to P_I1 or P_I2, was also observed in several animals with notable ancestry to one or more of the other three genetic clusters. The animals with high assignment to the P_I4 cluster had a mixture of NW and OW mtDNA haplotypes with either a gray wolf or eastern wolf Y-intron haplotype. The majority of animals with high assignment to the P_I4 cluster had the C3, C13 or C22 mtDNA haplotype, which were the most prevalent haplotypes as mentioned above, and none of these haplotypes were observed in animals with high assignment to P_I1 or P_I2. The combination of a coyote mtDNA haplotype and a gray wolf Y-intron haplotype was rare, being observed in only six animals (Table 2.1, note that C13 and C14 are interpreted as haplotypes derived primarily from *C. lycaon* in the study region, see Discussion). The OW mtDNA haplotypes occurred exclusively in animals having either the gray wolf or eastern wolf Y-intron haplotype (Table 2.1). Also, the OW mtDNA haplotypes occurred exclusively in animals having high assignment to P_I4 or P_I5, or mixed assignment to P_I3, P_I4, and P_I5, with the exception of one individual that had a mixed assignment to P_I1, P_I2 and P_I4. The gray wolf Y-intron haplotype occurred predominantly in animals having high assignment to P_I4 or P_I5, with a few animals having notable assignment to P_I3, and only two animals having high assignment to P_I1 or P_I2. The eastern wolf Y-intron haplotype occurred predominantly in animals having high assignment to P_I4, however, there were several animals with high assignment to P_I2 and one animal that had mixed ancestry to P_I3, P_I4 and P_I5.

The overall notable trends for the combined genetic data were: 1) coyote mtDNA was observed in animals with high assignment to P_I1 or P_I2; 2) eastern wolf or gray wolf mtDNA was observed predominantly in animals with eastern wolf or gray wolf Y-intron and high assignment to P_I4; and 3) rare co-occurrence of gray wolf Y-intron and coyote mtDNA haplotypes.

Discussion

Canid samples (n = 404) from the WGLR were genetically characterized using three genetic markers, and compared to wolves and coyotes from other regions in North America. Based on mtDNA and Y-intron data from this study and others (e.g. Grewal 2001; Shami 2002), and considering the overall relative clustering of groups based on the microsatellite genotypes, the populations inferred by STRUCTURE can be assigned a species or hybrid designation (P_In = I-model; P_Fn = F-model): P_I1 and P_F1 = *C. latrans* (Texas); P_I2 and P_F2 = *C. latrans-lycaon* hybrids (Frontenac Axis); P_I3 and P_F3 = *C. lycaon* (Algonquin); P_I4 = *C. lupus-lycaon* hybrids (Manitoba, Minnesota, Wisconsin, Michigan, northwestern/northeastern Ontario and Quebec); P_I5 and P_F7 = *C. lupus* (Northwest Territories). The animals belonging to P_F4 (Minnesota, Wisconsin, Michigan and northwestern Ontario), P_F5 (northeastern Ontario and Quebec) and P_F6 (Manitoba) all represent *C. lupus-lycaon* hybrids, and are collectively representative of the animals comprising P_I4 (Figure 2.5).

Haplotype C13 occurred in high frequency in the western Great Lakes states (n = 88 of 215; 41%) and northwestern Ontario (n = 25 of 92; 27%), and haplotype C14 occurred in relatively high frequency in northeastern Ontario (n = 23 of 97; 24%) (Figure

2.3). Haplotypes C13 and C14 were observed predominantly in *C. lupus-lycaon* hybrids and not coyotes, therefore they were interpreted to represent mtDNA haplotypes derived primarily from *C. lycaon* in the study region, even though they clustered with coyote sequences (Figure 2.2). Mitochondrial haplotypes C13 and C14 have both been observed in eastern coyotes from southeastern Ontario (Grewal *et al.* 2004). Haplotype C14 has also been observed in non-hybridizing coyotes in Nebraska (C14 is identical to haplotype la033 in Hailer and Leonard 2008), however, haplotype C13 has not been observed in non-hybridizing populations of coyotes (e.g. Wilson *et al.* 2003; Hailer and Leonard 2008; C13 not observed in Saskatchewan coyotes, data not shown). Therefore haplotype C13 is suggested as being of eastern wolf origin through the introgressive hybridization of a coyote haplotype and subsequent divergence to become eastern wolf specific (see Chapter 3). The presence of haplotype C14 in non-hybridizing populations of coyotes indicates that it is a *C. latrans* haplotype and suggests the introgression of haplotype C14 into *C. lupus-lycaon* hybrids through previous introgression into eastern wolves. Thus, haplotypes C13 and C14 are both interpreted as being derived from *C. lycaon* in the study region, but through different mechanisms. These findings illustrate the extensive hybridization that has occurred between eastern wolves and coyotes, which has resulted in haplotypes of both species being observed in various hybrids, i.e. eastern wolf haplotypes occur in eastern coyotes and putative coyote haplotypes occur in *C. lupus-lycaon* hybrids.

The ancestral Y-intron haplotype was observed exclusively in animals with coyote mtDNA and having high assignment to P_I1 or P_I2, with the exception of one animal having a C14 mtDNA haplotype and mixed assignment to P_I3 and P_I4. Therefore, based on the samples analyzed, the ancestral Y-intron haplotype is interpreted to be generally indicative of a coyote paternal contribution in the study region, where the coyote specific Y-intron haplotype has not been observed (i.e. CANInt3 from Shami 2002). However, it is recognized that the ancestral Y-intron haplotype does occur in wolves in North America (Shami 2002), and thus does not exclusively represent a coyote paternal contribution.

The results of the FCA were concordant with the results from STRUCTURE, revealing approximately five genetic clusters. Given that predominantly gray wolf and eastern wolf mtDNA and Y-intron haplotypes occurred in P_I4 animals, this population was concluded to represent animals containing genetic material derived from both gray wolves and eastern wolves. Therefore, P_I4 represents a population of *C. lupus-lycaon* hybrids that extends from the western Great Lakes states into northwestern Ontario, and also into Manitoba, northeastern Ontario and Quebec (Figure 2.5). Coyotes from the western Great Lakes states and northern Ontario showed high assignment to P_I1 or P_I2, and this is confirmed by the FCA (Figure 2.6). Only one coyote mtDNA haplotype (C9) and no ancestral Y-intron haplotypes were observed in P_I4 animals, and there was a very low level of admixture between P_I4 and either P_I1 or P_I2 (Figure 2.5). These findings indicate that *C. lupus-lycaon* hybrids do not breed with coyotes.

The splitting of Manitoba, and northeastern Ontario and Quebec from P_I4 under the F-model in STRUCTURE is reflected in the results of the FCA, which showed samples from these groups deviating noticeably from the core cluster of the western Great Lakes states and northwestern Ontario samples (Figure 2.6). The Manitoba (P_F6), and northeastern Ontario and Quebec (P_F5) populations still represent *C. lupus-lycaon* hybrids based on mtDNA (Wilson *et al.* 2003; Grewal *et al.* 2004) and Y-intron haplotypes (i.e. in northeastern Ontario). There was a notable difference in mtDNA and Y-intron haplotype composition between northeastern Ontario wolves and those from the western Great Lakes states and northwestern Ontario. The gray wolf Y-intron haplotype occurred in much higher frequency than the eastern wolf Y-intron haplotype in northeastern Ontario compared to in the west (Figure 2.4). Also, mtDNA haplotype C14 was observed in relatively high frequency in northeastern Ontario compared to C13, which was the predominant haplotype to the west (Figure 2.3). These differences in haplotype composition suggest that the F-model clustering of northeastern Ontario as separate from P_I4 represents real population differentiation. The separate clustering of Manitoba under the F-model is also supported by the greater proportion of gray wolf mtDNA haplotypes observed relative to eastern wolf haplotypes in Manitoba (Wilson *et al.* 2003) compared to the WGLR, suggesting Manitoba *C. lupus-lycaon* hybrids are proportionally more gray wolf, although the pairwise F_{ST} values do not support this (Table 2.2). Regardless, the results are suggestive of an east to west genetic cline of *C. lupus-lycaon* hybrids in northeastern North America. Collection of more samples from northern Ontario, Quebec and Manitoba is necessary to further assess the genetic differentiation between the various *C. lupus-lycaon* populations. The analysis of linked and unlinked loci in STRUCTURE, implementing the linkage model, is recommended and could provide information on the time since hybridization for the *C. lupus-lycaon* populations, which may indicate a possible east-west difference in time since hybridization between eastern wolves and gray wolves if it exists. The western *C. lupus-lycaon* hybrids may represent a longer-standing hybrid than the eastern *C. lupus-lycaon* hybrids (see Chapter 3), however, the analysis of historic samples from both regions is likely also required for a conclusive assessment to be made.

The pairwise estimates of F_{ST} revealed a relatively low genetic differentiation between Texas coyotes and Frontenac Axis eastern coyotes. The eastern wolves of Algonquin Park exhibited least genetic differentiation to Frontenac Axis eastern coyotes, which reflects their geographic proximity and sharing of eastern wolf and coyote genetic material (e.g. Grewal *et al.* 2004). Genetic differentiation between Northwest Territories gray wolves and Texas coyotes was relatively high, as was expected given their relatively distant evolutionary relationship. The *C. lupus-lycaon* hybrids from the western Great Lakes states and northwestern Ontario showed relatively low genetic differentiation to the *C. lupus-lycaon* hybrids from northeastern Ontario and Quebec, generally consistent with the STRUCTURE and FCA results.

A notable number of eastern coyotes were observed in northeastern Ontario, but primarily in the southern portion of this region, indicating that the range of eastern coyotes extends into northeastern Ontario. The occurrence of several animals with high assignment to P_I2 was also observed in the western Great Lakes states; however this does not necessarily suggest that eastern coyotes are present in this region. This is reflected in the FCA (Figure 2.6), in which samples from the western Great Lakes states clustered at the fringe of the Frontenac Axis group, somewhat intermediate to the Texas and Frontenac Axis samples, and among the samples from northwestern Ontario that had high assignment to P_I1 instead of P_I2. This contrasts with the animals from northeastern Ontario that had high assignment to P_I2, which generally clustered at the core of the Frontenac Axis group in the FCA (Figure 2.6) and likely represent eastern coyotes similar to those found in southeastern Ontario. These results suggest that the coyote groups used in the analysis may not be representative of the coyotes from the western Great Lakes states and northwestern Ontario, rather they may provide the most closely related populations for ancestry assignment of WGLR coyotes. Non-hybridizing coyote populations from closer regions may provide a more accurate assessment of the distribution and genetic ancestry of coyotes from the WGLR to confirm the presence, or more likely the absence of eastern coyotes (i.e. *Canis latrans X lycaon*) in the WGLR. Regardless of this valid concern, the coyote groups included in the analysis did effectively identify coyote-like animals as different from the wolves of P_I4 and the other two wolf populations. The multiple streams of genetic data collectively suggest that wolf-coyote hybridization in the WGLR is rare, however, the observation of a few individuals that were classified as having mixed wolf-coyote ancestry suggests that *C. lupus-lycaon* hybrids are potentially capable of breeding with sympatric coyotes. A larger sampling of putative pure coyotes from the WGLR is required to further assess their relationship to the *C. lupus-lycaon* hybrids.

The finding that *C. lupus-lycaon* hybrids occupy the WGLR and do not breed with sympatric coyotes contrasts with previous studies that suggested *lupus/latrans* hybridization was prevalent in this region (e.g. Lehman *et al.* 1991). However, the data from some of these previous studies can be interpreted to support to the findings of this study. For instance, Lehman *et al.* (1991) reported the observation of "coywolf" (i.e. NW) mtDNA genotypes in wolves from northeastern Minnesota and northwestern Ontario, suggesting that the combination of NW and OW mtDNA was indicative of *lupus/latrans* hybridization. However, when the eastern wolf is considered as a NW replacement for the coyote given their data, the results are consistent with *lupus/lycaon* hybridization. Specifically, Lehman *et al.* (1991) reported "coywolf" mtDNA genotypes W7 and W9 were observed in high frequency in hybridizing wolves from northeastern Minnesota and northwestern Ontario, which based on relative frequencies are probably analogous to *C. lycaon* mtDNA haplotypes C13 and C3 observed in this study. The similarity of eastern wolf and coyote mtDNA haplotypes previously led researchers to mischaracterize hybridization when the eastern wolf is not integrated into the interpretation of the genetic data. In the absence of supporting data from nuclear DNA the differences between hybridizing wolves to the west and east of the Great Lakes were not properly assessed.

The finding that *C. lupus-lycaon* hybrids occupy the WGLR and do not breed with sympatric coyotes based on genetic analyses is supported by morphological analyses of animals from this region (e.g. Nowak 1995 & 2003). There is no evidence to support wolf-coyote hybridization extending beyond southeastern Ontario and Quebec based on morphology, ecology or behaviour, and wolves of Minnesota and northwestern Ontario are fully wolf-like in those respects (Nowak 2003). A review of wolf taxonomy based on morphological studies supported wolf (*C. lupus lycaon*) populations from Minnesota being more closely related to gray wolves (*C. lupus nubilus*) than to wolf (*C. lupus lycaon*) populations from Quebec and southeastern Ontario (see Nowak 1995). The review supported the suggestion of Kolenosky and Standfield (1975) that northwestern Ontario populations are closely related to Minnesota populations and are separated by a sub-specific line from populations in southeastern Ontario, with larger wolves to the northwest and smaller wolves to the southeast in Ontario. The classification of canids in the Great Lakes region based on morphology (Nowak 1995) is congruent with the classification based on genetics from this study.

The interpretation of *Canis* hybridization in northeastern North America based on current data should be that wolves in the WGLR represent *C. lupus-lycaon* hybrids that do not breed with sympatric coyotes, whereas wolves in the southeastern Great Lakes region represent *C. latrans-lycaon* hybrids (i.e. eastern coyotes). Algonquin Park, located in central Ontario, appears to represent a putatively purer eastern wolf population, however, introgression of coyote and gray wolf genetic material has occurred (Grewal *et al.* 2004). The degree to which *C. lupus-lycaon* hybrids may breed with eastern coyotes is presently unclear, however data from this study suggests that it is not common. The presence of the same coyote mtDNA haplotypes in both eastern coyotes and *C. lupus-lycaon* hybrids (i.e. haplotype C14) would suggest that these two different types of hybrids do interbreed, however, the nuclear DNA profiles indicate that coyote genes are not prevalent in the *C. lupus-lycaon* hybrids, even those containing coyote mtDNA haplotypes. This supports the introgression of putative coyote mtDNA into *C. lupus-lycaon* hybrids through previous introgression into eastern wolves (i.e. haplotype C14). Further sampling of central Ontario, near Algonquin Park, where the ranges of *C. lupus-lycaon* hybrids and eastern coyotes likely converge is required to further assess this issue, and is important for determining the extent of a potential three species hybrid complex.

The genetic composition of extant wolves in the WGLR is consistent with Wisconsin and Michigan being recolonized by wolves coming from Minnesota and northwestern Ontario, as indicated by the large homogeneous wolf population that currently occupies the region. The population structure of WGLR wolves suggests high levels of gene flow and connectivity, and accordingly conservation and management strategies should focus on conserving this genetic connectivity. The combination of eastern wolf and gray wolf genetic material in WGLR wolves should provide adaptive evolutionary potential to changing environmental factors such as prey, climate and habitat. Although the wolf population is presently not breeding with sympatric coyotes in the WGLR, it is uncertain how environmental changes in the future may affect the hybridization dynamics of canids in this region. However, based on the fact that WGLR wolves occurred at low densities for decades sympatric with coyotes prior to their recovery, and they presently show no notable evidence of coyote introgression, the threat of wolf-coyote hybridization does not seem significant. Regardless, genetic monitoring of WGLR wolves should continue if potential hybridization with coyotes is considered a major concern for their conservation and management, given that changes in the landscape and climate may impact the dynamics of *Canis* populations in the future.

The findings of this study indicate that wolf recovery efforts have been successful in restoring a large, genetically homogeneous wolf population to the WGLR, and state management plans should focus on maintaining adequate numbers of wolves to ensure their long-term persistence in the region, rather than worrying about the genetic ancestry of, and relationships among, canids in this region.

Chapter 3: Genetic analysis of historic western Great Lakes region wolf samples reveals early *Canis lupus/lycaon* hybridization

Abstract

The genetic status of wolves in the western Great Lakes region has received increased attention following the decision to remove them from protection under the U.S. Endangered Species Act. A recent study of mitochondrial DNA suggested that the recovered wolf population is not genetically representative of the historic population. Microsatellite genotype data of three historic samples is presented and compared to extant populations, and published genetic data are interpreted to show that the pre-recovery population was admixed over a century ago by eastern wolf (*Canis lycaon*) and gray wolf (*C. lupus*) hybridization. The DNA profiles of the historic samples are similar to those of extant animals in the region, suggesting that the current Great Lakes wolves are representative of the historic population.

Introduction

The ongoing debate over the evolutionary history and genetics of *Canis* populations in northeastern North America has become of immediate relevance to the conservation and management of wolves given the recent U.S. federal de-listing of the Western Great Lakes Distinct Population Segment (FWS 2007). Various studies over the last two decades have focused on the genetic composition of *Canis* in the Great Lakes Region (GLR), and genetic data have shown that wolves in this region contain genetic material of Old World (OW) and New World (NW) evolved species (Lehman *et al.* 1991), yet much uncertainty remains about their relationship with other populations.

Recently, Leonard and Wayne (2008) reported on mitochondrial DNA (mtDNA) analyses of historic GLR wolves, suggesting that pre-recovery wolves were dominated by haplotypes distinct from gray wolves (*Canis lupus*) and western coyotes (*C. latrans*) that they propose are from an endemic North American wolf referred to as the “Great Lakes wolf”. They interpreted the current population to be admixed, deriving primarily from *lupus/latrans* hybridization, with minor contributions from the “Great Lakes wolf”, and concluded that recently de-listed GLR wolves are not genetically representative of the pre-recovery population. Their interpretation fails to recognize extensive genetic data on the NW evolved eastern wolf (*C. lycaon*), the mtDNA sequences of which are close to those of *C. latrans* (Wilson *et al.* 2000 & 2003). The eastern wolf has been shown to be a distinct species (Wilson *et al.* 2000) that is capable of hybridizing with both coyotes and gray wolves across its range (see Kyle *et al.* 2006), acting as the conduit of *Canis* hybridization in northeastern North America. Some researchers do not agree with the suggestion that the current GLR population contains animals derived from *lupus/latrans* hybridization, as these sympatric species do not hybridize in western North America (see Kyle *et al.* 2006).

Nuclear microsatellite and mtDNA data from three pre-recovery samples from the western GLR are presented, and mtDNA haplotypes from Leonard and Wayne (2008) are compared to those reported by Wilson *et al.* (2000 & 2003) as evidence that the present and pre-recovery wolf populations in the western GLR are genetically similar and are derived from *lupus/lycaon* hybridization.

Materials and Methods

Samples and DNA extraction

DNA was extracted from three historic C*anis* samples provided by the University of Wisconsin Zoological Museum (Table 3.1) using a DNeasy Blood & Tissue Kit (Qiagen Inc., Mississauga, ON) in a dedicated ancient DNA laboratory.

Table 3.1: Historic *Canis* sample information.

museum catalog#	sex	state	country	date
8626	male	Minnesota	Itasca	Spring 1900
8627	male	Minnesota	Itasca	February 1899
11856	--	Wisconsin	Ashland	Winter 1907/08

Mitochondrial Control Region Sequencing

A 343-347 base-pair (bp) fragment of the mtDNA control region was amplified using the primers described in Chapter 2 and under similar conditions with 0.1 μg/μL of BSA included in the reaction. Contamination was monitored during extraction and PCR using negative controls. PCR products were cleaned with Exosap-IT (USB Corporation, Cleveland, OH) prior to sequencing on a MegaBACE 1000 (GE Healthcare). The sequence of sample 11856 was confirmed from an independent amplification. Sequences were edited, aligned and compared to known haplotypes in Bioedit (Hall 1999). Refer to Chapter 2 for a description of the sequences.

Microsatellite Genotyping

Amplification of twelve nuclear microsatellite loci was attempted for each sample (refer to Chapter 2), and homozygous genotypes were confirmed by repeated amplification. Two samples were genotyped at twelve loci and the remaining sample at eight loci.

Genetic analysis

Alleles were scored in Genemarker (v1.7, SoftGenetics LLC, State College, PA) and the data were analyzed using STRUCTURE (v2.2, Pritchard *et al.* 2000; Falush *et al.* 2003, 2007) including the following samples genotyped at the same twelve loci as the historic samples: Northwest Territories (n = 56); Manitoba (n = 36); Minnesota (n = 53); Wisconsin (n = 48); Michigan (n = 90); Northwestern Ontario (n = 87); Northeastern Ontario (n = 93); Quebec (n = 34); Algonquin Provincial Park (n = 54); Frontenac Axis (n = 52); Texas (n = 24). Based on a previously described STRUCTURE analysis (see Chapter 2) the number of populations K for the data set was determined to be five (based on I-model). The admixture model of STRUCTURE was run at K = 5 with ten repetitions of 10^6 iterations following a burn-in period of 250,000 iterations, assigning each historic sample a proportional membership to each of the five inferred genetic clusters. All ten STRUCTURE runs had similar posterior probabilities (Ln P[D]) and variances; therefore the proportional memberships of the historic samples were taken from the run having the lowest variance and highest posterior probability.

To supplement the results from STRUCTURE, a non-model based Factorial Correspondence Analysis (FCA) was performed on the microsatellite data for individual canids using GENETIX (v4.05, Belkhir *et al.* 2004). Two factorial components FC-1 and FC-2, which accounted for 5.74% and 3.23% of the total inertia respectively, were plotted to visualize the clustering of the historic samples in relation to the other sample groups.

Results

The informative variable ~230 bp region of the "Great Lakes wolf" mtDNA control region haplotypes within Leonard and Wayne (2008), denoted as GL(X), was compared to sequences described in Wilson *et al.* (2000 & 2003), denoted as C(X). As previously identified by Leonard and Wayne (2008), haplotype GL1 was identical to *C. lycaon* haplotype C1. However, other similarities were observed among haplotypes from both studies (Table 3.2), including two GL(X) haplotypes identical to *C. lycaon* haplotype C3. It is of interest that three GL(X) haplotypes were identical to a coyote-clustering sequence, haplotype C13, which has not been found in extant non-hybridizing coyote populations but is present throughout the distribution of *C. lycaon* (Wilson *et al.* 2003; Grewal *et al.* 2004).

The three historic samples were sequenced at the mtDNA control region (294-322 bp) and assigned haplotypes based on the ~230 bp region (Table 3.3). The two haplotypes observed in the three samples, C13 (n = 2) and C1 (n = 1), were identical to haplotypes found by Leonard and Wayne (2008) (Table 3.2).

Based on the genotypes at the microsatellite loci five populations were identified by STRUCTURE: P1 = Texas (western coyotes); P2 = Frontenac Axis (eastern coyotes); P3 = Algonquin (eastern wolves); P4= Manitoba, Minnesota, Wisconsin, Michigan, Quebec and northwestern/northeastern Ontario (eastern/gray wolves); P5 = Northwest Territories (gray wolves). The admixture proportions of the three historic samples revealed their highest proportional memberships were to P4, and one sample had 25% assignment to P3 (Table 3.3). The individual-based FCA clustered the historic samples

Table 3.2: Comparison of variable sites between GL(X) and C(X) haplotypes. Dot indicates same base as uppermost row; dash indicates no base present. Superscripts indicate identical haplotypes within ~230 bp region of comparison. Note C(X) haplotypes do not span entire alignment of GL(X) haplotypes.

haplotype	variable site within GL(X) haplotypes														
	100	159	170	230	231	232	247	249	253	264	265	266	268	271	301
GL1[a]	A	C	C	T	C	C	T	G	C	T	T	C	C	A	T
GL2 & GL19[b]	.	T	.	.	.	.	C	.	.	C	.	.	.	.	.
GL10, GL17 & GL18[c]	G	.	.	.	T	T	C	A	T	.	.	.	.	.	C
GL11[d]	G	.	-	C	.	T	C	A	T	.	.	.	.	.	C
GL12[e]	G	.	.	C	.	T	C	A	.	.	.	.	.	G	C
GL13[f]	G	.	.	C	.	T	C	A	T	.	.	.	.	G	C
GL16[g]	G	.	-	.	.	T	C	A	T	C	C	T	T	G	C
C1[a]	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
C3[b]	.	T	.	.	.	.	C	.	.	C	.	.	.	.	.
C9[g]	G	.	-	.	.	T	C	A	T	C	C	T	T	G	C
C13[c]	G	.	.	.	T	T	C	A	T	.	.	.	.	.	C
C14[f]	G	.	.	C	.	T	C	A	T	.	.	.	.	G	C
C17[e]	G	.	.	C	.	T	C	A	.	.	.	.	.	G	C
C19[d]	G	.	-	C	.	T	C	A	T	.	.	.	.	.	C

amongst samples from the Manitoba, western Great Lakes states, Quebec and northwestern/northeastern Ontario groups (Figure 3.1).

Table 3.3: Mitochondrial DNA haplotypes and admixture proportions of historic *Canis* samples. Populations inferred by STRUCTURE: P1 = Texas (western coyotes); P2 = Frontenac Axis (eastern coyotes); P3 = Algonquin (eastern wolves); P4= Manitoba, Minnesota, Wisconsin, Michigan, Quebec and northwestern/northeastern Ontario (eastern/gray wolves); P5 = Northwest Territories (gray wolves).

museum catalog#	haplotype	# loci	admixture proportions				
			P1	P2	P3	P4	P5
8626	C13	12	0.009	0.013	0.042	0.922	0.015
8627	C13	8	0.013	0.012	0.250	0.673	0.053
11856	C1	12	0.011	0.015	0.097	0.814	0.063

Discussion

The genetic analyses revealed that the three historic samples from the western GLR have a mixed ancestry deriving primarily from sample groups representing eastern wolves and gray wolves (i.e. P4). The historic samples did not cluster significantly with either of the two groups composed of coyote-like animals (i.e. P1 and P2). The results of the FCA were concordant with the results from STRUCTURE with the historic samples clustering with wolves and not coyotes. Both OW and NW mtDNA haplotypes occur in P3 (Grewal *et al.* 2004) and P4 (see Chapter 2; Wilson *et al.* 2008), whereas only OW haplotypes occur in P5 (Wilson *et al.* 2003) and only NW haplotypes occur in P1 (Wilson *et al.* 2003) and P2 (Grewal *et al.* 2004) (Figure 3.1). Given that OW and NW haplotypes occur in the group for which the historic samples had their highest proportional memberships (i.e. P4), the historic samples were concluded to represent animals containing genetic material derived from both gray wolves (OW) and eastern wolves (NW), and not coyotes.

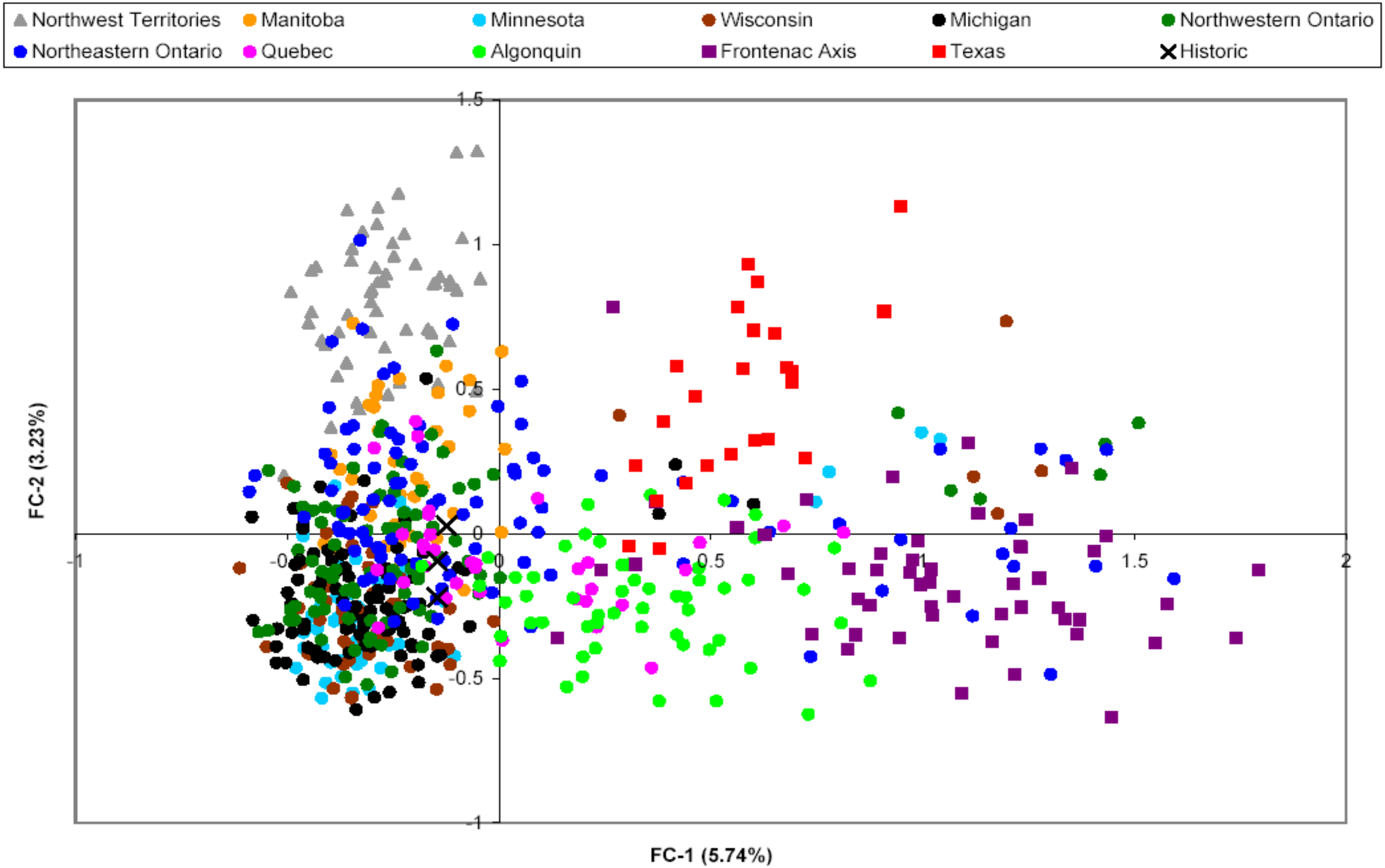


Figure 3.1: Factorial correspondence analysis of microsatellite loci for *Canis* sample groups and historic samples. Symbol type of sample group indicates mtDNA haplotypes present: circle = Old World and New World; triangle = Old World; square = New World.

The occurrence of haplotype C13 in two historic samples that clustered with non-coyote groups based on nuclear microsatellite data (Table 3.3) supports the interpretation that C13 is a *C. lycaon* haplotype, as does its apparent absence from extant coyote populations in regions with no evidence of wolf-coyote hybridization, such as Texas (Wilson *et al.* 2003) and Nebraska (Hailer and Leonard 2008). The occurrence of haplotype C13 in wolves 100 years ago is likely the result of one of three possible scenarios: 1) C13 evolved in the common ancestor of coyotes and eastern wolves and was perpetuated in both species when they diverged (i.e. incomplete lineage sorting); 2) *lycaon/latrans* hybridization occurred earlier, i.e. pre-European settlement, whereby C13 was introgressed into *C. lycaon* and subsequently lost from the source *C. latrans* population; and 3) an ancestral coyote haplotype was introgressed into the *C. lycaon* lineage during the Pleistocene or sometime prior to European settlement and subsequently diverged to become eastern wolf specific. The latter scenario would explain why C13 clusters closer to coyote sequences than eastern wolf sequences (Wilson *et al.* 2003). The loss of a mtDNA haplotype from a source *C. latrans* population seems unlikely given the rapid population expansion of the species and the apparent absence of C13 from non-hybridizing coyote populations. The divergence of haplotype C13 from the eastern wolf clade and its absence in western coyote populations (Wilson *et al.* 2003) supports C13 as being of eastern wolf origin through introgressive hybridization and subsequent divergence, and not incomplete lineage sorting.

The GL(X) haplotypes that were identical to haplotypes C1, C3, and C13 (Table 3.2) occurred in samples from the western Great Lakes states (Leonard and Wayne 2008), further supporting the presence of *C. lycaon* genetic material in animals in this region.

The ability of the eastern wolf to hybridize with both coyotes and gray wolves complicates species assignments based on mitochondrial sequences and leads to questions concerning their validity, because the possibility exists of NW haplotypes occurring in *C. lupus-lycaon* hybrids and OW haplotypes occurring in *C. latrans-lycaon* hybrids. This issue has important ramifications for previous taxonomic interpretations based solely on mtDNA.

The DNA profiles presented here indicate that the pre-recovery western GLR wolf population was probably composed of *C. lupus-lycaon* hybrids, suggesting that eastern wolves and gray wolves hybridized historically (i.e. >100ya). To date no *C. lupus* mtDNA has been observed in pre-recovery western GLR samples, however, based on the nuclear microsatellite data, these animals are genetically similar to the present animals which have both gray wolf and eastern wolf mtDNA haplotypes. Limited sampling has likely failed to resolve the presence of *C. lupus* mtDNA in the western GLR during pre-recovery times (Nowak 2002), accepting that it may have been present at a lower frequency than in the current population. Several factors may have contributed to the observed absence or suspected lower abundance of gray wolf haplotypes in pre-recovery western GLR wolves: 1) population bottleneck; 2) genetic drift; and 3) sex-biased *lupus/lycaon* hybridization.

A probable scenario is that re-colonizing wolves originating from Minnesota, Manitoba and northwestern Ontario, containing *C. lupus* and *C. lycaon* mtDNA haplotypes, moved east into Wisconsin and continued into Michigan's Upper Peninsula. This may have resulted in current wolf populations exhibiting *C. lupus* mtDNA in higher frequency than in pre-recovery wolves from the western GLR. Previous research supports the presence of both *C. lycaon* and *C. lupus* haplotypes in Manitoba and northwestern Ontario (Wilson *et al.* 2003; see Chapter 2), which represents a potential and likely source of immigrants for the recovering Wisconsin and Michigan populations. Genetic analysis of extant *Canis* samples from the western GLR, based on a variety of genetic markers, supports *lupus/lycaon* hybridization (see Chapter 2), as does previous research (Mech and Federoff 2002; Wilson *et al.* 2008). The hypothesis that the current Great Lakes wolf population is derived from *lupus/latrans* hybridization is rejected by the data (Figure 3.2).

The conclusion that the recovered Wisconsin and Michigan wolf populations are composed of *C. lupus-lycaon* hybrids has implications for the de-listing of gray wolves in the western GLR, and an important issue to consider is when the *lupus/lycaon* hybridization occurred. Given the genetic similarities between the pre-recovery and extant western GLR wolves, current and future conservation and management actions should focus on conserving the current wolf population and maintaining gene flow across its range, and not attempt to interfere with hybridization dynamics in the hope of achieving a “pure” animal or desired phenotype.

Acknowledgements

Thank you to Jennifer Leonard for providing sequence data for the haplotype comparisons, and Paula Holahan and Adrian Wydeven for providing the historic samples for analysis.

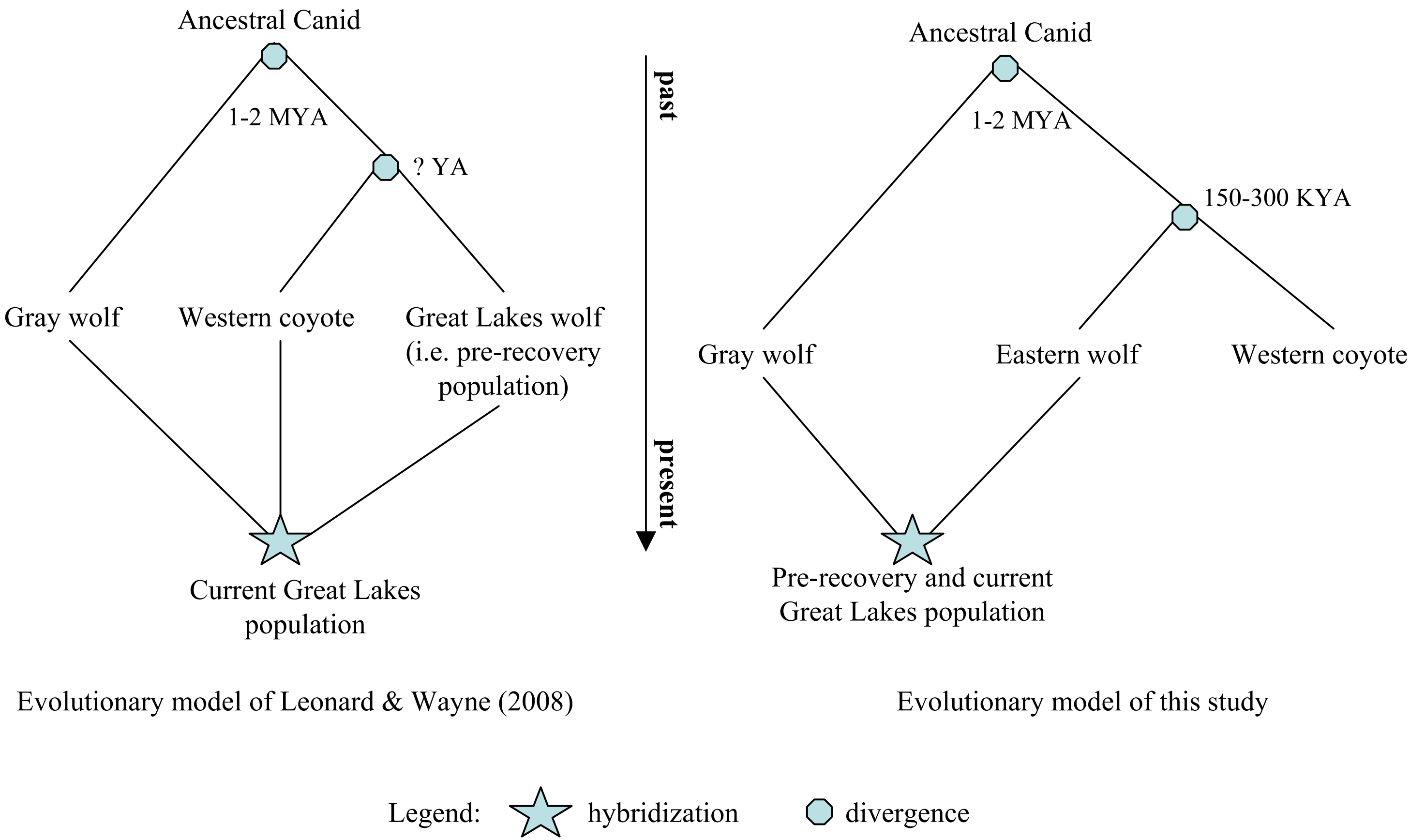


Figure 3.2: Comparison of *Canis* evolution hypotheses.

Chapter 4: General Discussion

Summary of Findings

Genetic analyses conducted on *Canis* samples from the western Great Lakes Region (WGLR) and surrounding localities indicate that the extant wolves occupying northwestern Ontario, Minnesota, and the recovered populations of Wisconsin and Michigan represent canids derived from hybridization of gray wolves (*C. lupus*) and eastern wolves (*C. lycaon*). The genetic data indicate that wolves do not hybridize with coyotes (*C. latrans*) in the WGLR, unlike in southeastern Ontario where *latrans/lycaon* hybridization has been extensive (e.g. Wilson *et al.* 2008), congruent with morphological studies (see Nowak 1995). Genetic analysis of three century-old wolf samples from the pre-recovery WGLR population revealed that they had similar DNA profiles to wolves that currently occupy the region. This finding was interpreted to suggest that hybridization occurred between eastern wolves and gray wolves over a century ago. The extant animals in the WGLR were determined to be representative of animals that occupied the region historically, suggesting that wolf recovery efforts have been successful in the WGLR.

Discussion of Canis in Northeastern North America

The gray wolf historically occupied the majority of North America with the exception of the eastern deciduous forests, which were occupied by the eastern wolf (Nowak 1995 & 2002). The *C. lupus-lycaon* hybrids that occupy the current WGLR wolf population likely resulted from historic hybridization between eastern wolves and gray wolves. The WGLR represents a region where their distributions likely overlapped

(Nowak 2002). This hybridization may have occurred during interglacial periods of the Pleistocene when they came into contact after prior isolation. Alternatively this hybridization may be more recent, having occurred following European colonization, which may have led to the breakdown of post-glacial reproductive barriers previously maintained by habitat and prey specificities (Kolenosky and Standfield 1975; Nowak 2002). The occurrence of *lupus/lycaon* hybridization over a century ago seems plausible given that 1) gray wolves decreased in abundance in the western Great Lakes states due to human persecution since the mid 1800s (FWS 2007) and 2) eastern wolves expanded their range into this region following the northward expansion of white-tailed deer (Kolenosky and Standfield 1975; Nowak 2002). These two points suggest that the two species probably came into contact in disproportionate abundances or at low density and under disrupted population and social structure, and these factors may have contributed to hybridization. However further investigation is required to determine if this hybridization occurred pre- versus post-European colonization, and this assessment may be accomplished by the analysis of linked microsatellite loci, which can provide an estimate of the time since admixture between populations (Falush *et al.* 2003). The conservation merit of a natural hybrid population is likely perceived as greater than that of a hybrid population resulting from human influences (e.g. Allendorf *et al.* 2001). However, the cause of hybridization should not preclude sustaining a hybrid wolf population that fills the ecological role of a top canid predator in the WGLR, especially considering that unhybridized forms of the parental species likely no longer exist in the hybrid zone that encompasses the region. Similar logic applies to the conservation merit of eastern coyotes.

The eastern wolf is the mediator of *Canis* hybridization in northeastern North America, breeding with both gray wolves and coyotes in the northwest and southeast portions of its range respectively (see Chapter 2; Kyle *et al.* 2006). The ability of eastern wolves to hybridize with gray wolves, an ability coyotes apparently lack, is likely facilitated by a combination of ecological and biological factors, including similar social structure and prey selection of both species (i.e. they are both wolves), and a relatively closer evolutionary relationship than between gray wolves and coyotes (e.g. Wilson *et al.* 2000). Eastern wolf genetic material occurs in eastern coyotes ranging from the northeastern United States (Way *et al.* submitted) into southeastern Ontario and southern Quebec (Grewal 2001), and eastern wolf genetic material occurs in *C. lupus-lycaon* hybrids ranging from Quebec across northern Ontario and the western Great Lakes states into Manitoba (see Chapter 2; Grewal 2001). The last putatively pure population representative of the eastern wolf is thought to reside in Algonquin Park, however, introgression of both coyote and gray wolf genetic material into the park animals (Grewal *et al.* 2004) suggests that the eastern wolf may not exist anywhere today in its original unhybridized form. Rather, the eastern wolf genome encompasses a broad geographic range, occurring in varying proportions in *C. lupus-lycaon* hybrids and eastern coyotes. However, the Algonquin Park ecosystem appears to be selecting for wolf-like animals and against coyote-like animals, showing limited gene flow to animals south of the park (Grewal *et al.* 2004), although it may be that eastern wolves first occupied and saturated the park and have naturally excluded coyotes, which would not necessarily represent selection. Regardless, the wolves of Algonquin Park are connected by gene flow to the larger wolf population that extends to the northwest and northeast of the park (Grewal *et* *al.* 2004), suggesting they do not represent a unique island population. Notwithstanding the previous statement, it could be argued that Algonquin Park wolves do exhibit notable morphological and genetic distinctiveness to canids from surrounding areas (see Chapter 2; Sears *et al.* 2003). Although a distinct species status cannot be justified for the park animals, their quasi-distinctiveness may reflect adaptation to the relatively stable park ecosystem, which may have maintained, or currently selects for, traits approximating those of the original eastern wolf in its unhybridized form. In general, one can only speculate, because unfortunately it is likely that no adequate sample of pure, unhybridized eastern wolves exists for comparison to the current park animals.

The possibility of a three-way hybrid complex may be a potential concern in northeastern North America, however, the nuclear DNA data from this study and others (see Kyle *et al.* 2006) indicate that gray wolves and coyotes do not interbreed. More specifically, *C. lupus-lycaon* hybrids do not interbreed with *C. latrans* or *C. latrans-lycaon* hybrids (i.e. eastern coyotes), or at least have not done so extensively in the region studied. However, it is recognized that the ranges of *C. lupus-lycaon* hybrids and eastern coyotes converge around central Ontario and in Quebec, and the potential for interbreeding between these two types of hybrids exists in these regions.

A large wolf population exists that extends across Quebec, Ontario, the western Great Lakes states, and Manitoba. This population represents a cline of sizes and phenotypes resulting from hybridization of *C. lycaon* with both *C. lupus* and *C. latrans* (see Kyle *et al.* 2006), and considering the high level of gene flow it is likely that some of the variation reflects ecological adaptation. The population contains genetic material of all three *Canis* species, and as a result maintains a high degree of genetic variation and adaptive evolutionary potential. Changes in landscape conditions and the distribution and abundance of prey are factors that will likely lead to selection for more wolf-like or more coyote-like animals (e.g. Geffen *et al.* 2004; Pilot *et al.* 2006).

Conclusions

The predicted changes in climate, due to global warming, will no doubt have a significant effect on the habitat and prey distribution of canids in North America. Ensuring that wolves are saturated in the landscape may be critical to limiting potential hybridization with eastern coyotes, the range of which could expand further north into regions currently dominated by wolves. However, if landscape conditions favour the selection of wolf-coyote hybrids it can be argued that such hybridization should not be impeded, to allow the animals to effectively adapt to their environment (e.g. Kyle *et al.* 2006). These issues will no doubt be important in determining the future distribution and dynamics of *Canis* species in North America. Current conservation and management plans for wolf populations in northeastern North America should focus on conserving habitats favourable to wolves in general (i.e. large wolf-like canids), and their prey species, and conserving genetic connectivity among wolf populations to maintain adaptive evolutionary potential and ensure their long-term persistence.

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Appendix

Table A1: Location and haplotype data of western Great Lakes region canid samples. Locations: NEON = northeastern Ontario; NWON = northwestern Ontario; MICH = Michigan; WISC = Wisconsin; MINN = Minnesota.

Sample	Location	Latitude	Longitude	Sex	mtDNA	OW/NW	Y-intron
CAN004048	NEON	46.50119	-80.99228	Male	C14	NW	4
CAN004051	NEON	45.86097	-82.47253	Male	C9	NW	1
CAN004053	NEON	45.91669	-82.46525	Female	C9	NW	
CAN004054	NEON	45.81383	-82.40523	Male	C99	NW	1
CAN004055	NEON	45.89040	-82.53138	Male	C19	NW	1
CAN004056	NEON	49.21324	-81.10678	Female	C22	OW	
CAN004057	NEON	49.23084	-81.17209	Male	C23	OW	4
CAN004058	NEON	49.21494	-81.24025	Male	C13	NW	2
CAN004059	NEON	46.50169	-80.96432	Male	C19	NW	1
CAN004073	NEON	49.28821	-81.24650	Female	C14	NW	
CAN004074	NEON	48.49627	-80.74878	Female	C14	NW	
CAN004075	NEON	48.99205	-80.70544	Male	C14	NW	2
CAN004076	NEON	49.29843	-81.17323	Female	C14	NW	
CAN004077	NEON	48.64952	-80.57794	Male	C9	NW	4
CAN004078	NEON	49.03954	-80.79013	Male	C14	NW	2
CAN004080	NEON	49.27855	-81.10280	Male	C14	NW	2
CAN004081	NEON	49.67595	-81.82230	Male	C22	OW	2
CAN004082	NEON	49.61328	-81.72327	Female	C22	OW	
CAN004083	NEON	49.22587	-81.51329	Male	C13	NW	2
CAN004084	NEON	48.65867	-80.65881	Female	C22	OW	
CAN004085	NEON	48.69988	-80.61532	Male	C13	NW	2
CAN004086	NEON	49.12421	-80.97442	Male	C22	OW	2
CAN004087	NEON	49.25304	-80.57596	Female	C22	OW	
CAN004088	NEON	48.84220	-81.26960	Female	C23	OW	
CAN004096	NEON	46.05245	-79.28824	Female	C19	NW	
CAN004144	NEON	46.23927	-80.85746		C19	NW	
CAN004166	NEON	49.22691	-81.63237	Male	C22	OW	2
CAN004167	NEON	49.29525	-81.62823	Male	C22	OW	2
CAN004183	NEON	46.65325	-80.94802	Female	C19	NW	
CAN004188	NEON	46.00792	-79.38550	Male	C14	NW	4
CAN004189	NEON	46.17431	-79.35386	Male	C9	NW	4
CAN004190	NEON	46.17900	-79.44643	Female	C14	NW	
CAN004199	NEON	46.24622	-80.85144	Female	C9	NW	
CAN004203	NEON	46.14654	-80.89107	Female	C14	NW	

Table A1 continued

Sample	Location	Latitude	Longitude	Sex	mtDNA	OW/NW	Y-intron
CAN004207	NEON	46.41337	-81.37887	Female	C3	NW	
CAN004221	NEON	49.82554	-83.50033	Male	C23	OW	2
CAN004222	NEON	49.77838	-83.54501	Female	C23	OW	
CAN004223	NEON	49.82057	-83.57976	Female	C23	OW	
CAN004224	NEON	49.82057	-83.65174	Female	C13	NW	
CAN004225	NEON	49.78831	-83.61699	Male	C23	OW	2
CAN004226	NEON	49.73866	-83.65422	Female	C13	NW	
CAN004227	NEON	49.73866	-83.59217	Female	C23	OW	
CAN004228	NEON	49.73618	-83.51522	Male	C23	OW	2
CAN004229	NEON	49.77838	-83.49537	Male	C22	OW	2
CAN004230	NEON	49.90717	-84.58721	Female	C22	OW	
CAN004243	NEON	49.21713	-80.72384	Female	C22	OW	
CAN004466	NEON	47.36644	-81.64591	Male	C22	OW	2
CAN004468	NEON	47.19183	-80.34289	Female	C3	NW	
CAN004469	NEON	46.30167	-80.86400	Male	C19	NW	4
CAN004470	NEON	47.33579	-81.47112	Male	C22	OW	4
CAN004471	NEON	46.28058	-80.73335	Male	C9	NW	2
CAN004472	NEON	46.30053	-80.88861	Male	C9	NW	2
CAN004473	NEON	49.21713	-80.83704	Male	C14	NW	2
CAN004474	NEON	47.33841	-81.55832	Female	C23	OW	
CAN004475	NEON	47.39247	-81.56442	Female	C14	NW	
CAN004476	NEON	46.12886	-81.09272	Male	C14	NW	1
CAN004477	NEON	47.52932	-81.87357	Female	C22	OW	
CAN004478	NEON	46.17333	-81.16082	Male	C9	NW	2
CAN004479	NEON	47.39334	-81.47635	Female	C13	NW	
CAN004482	NEON	46.23371	-80.85098	Female	C9	NW	
CAN004484	NEON	46.60338	-81.04855	Female	C3	NW	
CAN004485	NEON	49.29653	-80.83788	Female	C14	NW	
CAN004486	NEON	46.07772	-81.13228	Male	C17	NW	2
CAN004488	NEON	46.61218	-81.05550	Female	C22	OW	
CAN004489	NEON	49.29822	-80.72215	Male	C14	NW	2
CAN004502	NEON	49.29318	-81.51743	Female	C9	NW	
CAN004503	NEON	49.26274	-80.77791	Female	C19	NW	
CAN004505	NEON	46.24020	-80.84495	Female	C1	NW	
CAN004523	NEON	47.37329	-81.51908	Male	C22	OW	2
CAN004527	NEON	46.07007	-81.11149	Female	C17	NW	
CAN004530	NEON	46.07554	-81.16181	Male	C9	NW	4
CAN004608	NEON	49.09638	-81.03588	Female	C13	NW	
CAN004609	NEON	46.64925	-79.08754	Female	C22	OW	
CAN004610	NEON	49.26836	-81.19467	Female	C22	OW	

Table A1 continued

Sample	Location	Latitude	Longitude	Sex	mtDNA	OW/NW	Y-intron
CAN004613	NEON	49.09061	-80.90958	Male	C22	OW	2
CAN004614	NEON	48.76734	-80.67571	Female	C22	OW	
CAN004615	NEON	49.67508	-81.04612	Male	C14	NW	2
CAN004616	NEON	49.79153	-80.40323	Male	C14	NW	2
CAN004617	NEON	48.53661	-80.45751	Male	C19	NW	4
CAN004618	NEON	49.25716	-81.37161	Male	C14	NW	2
CAN004619	NEON	49.39379	-81.17451	Female	C22	OW	
CAN004620	NEON	49.12725	-80.78030		C13	NW	
CAN004621	NEON	47.87442	-83.34488	Male	C22	OW	2
CAN004622	NEON	47.91207	-83.27298	Female	C14	NW	
CAN004623	NEON	49.29834	-80.50694	Male	C14	NW	2
CAN004641	NEON	47.68316	-84.80911		C23	OW	
CAN004643	NEON	47.97791	-84.38289		C22	OW	
CAN004645	NEON	48.00073	-84.33220		C22	OW	
CAN004646	NEON	47.59339	-84.81914		C19	NW	
CAN004647	NEON	47.69495	-84.78016		C23	OW	
CAN004870	NEON	46.32384	-82.19490		C22	OW	
CAN004871	NEON	46.28032	-82.19812	Female	C1	NW	
CAN004873	NEON	46.21999	-82.22014		C9	NW	
CAN005263	NEON	49.77000	-83.98000	Male	C23	OW	2
CAN005264	NEON	49.78000	-83.99000	Male	C14	NW	2
CAN005265	NEON	49.77000	-83.97000	Male	C14	NW	2
CAN005266	NEON	50.40417	-83.14556	Male	C95	OW	2
CAN004032	NWON	49.73972	-86.59704	Male	C22	OW	2
CAN004064	NWON	49.59388	-94.28737	Female	C3	NW	
CAN004065	NWON	49.71222	-94.80889	Female	C23	OW	
CAN004067	NWON	48.76583	-91.62216	Male	C22	OW	4
CAN004068	NWON	48.84407	-91.78222	Male	C3	NW	4
CAN004070	NWON	49.06717	-91.53355	Female	C3	NW	
CAN004071	NWON	48.76137	-91.84722	Male	C13	NW	4
CAN004072	NWON	48.76000	-91.62000	Male	C22	OW	4
CAN004090	NWON	48.78937	-91.65865	Female	C3	NW	
CAN004091	NWON	49.08452	-91.51147	Female	C3	NW	
CAN004092	NWON	48.79610	-91.82763	Male	C3	NW	4
CAN004093	NWON	49.10661	-91.53461	Male	C13	NW	4
CAN004094	NWON	48.73585	-91.84640	Female	C3	NW	
CAN004095	NWON	48.75924	-91.61463	Female	C13	NW	
CAN004097	NWON	48.75794	-91.40808	Male	C3	NW	2
CAN004098	NWON	48.83037	-91.78137	Female	C3	NW	
CAN004100	NWON	49.08715	-91.55564	Male	C3	NW	4

Table A1 continued

Sample	Location	Latitude	Longitude	Sex	mtDNA	OW/NW	Y-intron
CAN004101	NWON	48.84664	-91.76595	Female	C13	NW	
CAN004102	NWON	48.74985	-91.82993	Male	C13	NW	2
CAN004103	NWON	48.76781	-92.61828	Female	C13	NW	
CAN004104	NWON	48.74983	-91.62169	Male	C13	NW	2
CAN004105	NWON	49.88997	-94.39587	Female	C13	NW	
CAN004106	NWON	49.42433	-94.26403	Male	C22	OW	4
CAN004107	NWON	49.41556	-94.30289	Male	C23	OW	4
CAN004108	NWON	49.84882	-86.55311	Male	C22	OW	2
CAN004109	NWON	51.01391	-93.81844	Male	C13	NW	2
CAN004110	NWON	49.78429	-94.52006	Male	C3	NW	2
CAN004112	NWON	51.02348	-93.84420	Female	C95	OW	
CAN004113	NWON	49.74491	-94.52536	Male	C22	OW	4
CAN004114	NWON	49.78505	-94.55187	Female	C3	NW	
CAN004115	NWON	49.76157	-94.54430	Male	C3	NW	2
CAN004116	NWON	48.95079	-88.33371	Female	C13	NW	
CAN004117	NWON	49.76384	-94.50719	Female	C22	OW	
CAN004118	NWON	49.75248	-94.48750	Female	C22	OW	
CAN004119	NWON	49.78050	-94.47387	Female	C13	NW	
CAN004120	NWON	49.80625	-94.50643	Female	C22	OW	
CAN004121	NWON	48.76440	-93.87868	Female	C3	NW	
CAN004123	NWON	48.81454	-93.93645	Male	C13	NW	4
CAN004124	NWON	48.76113	-93.96424	Male	C22	OW	2
CAN004125	NWON	48.76517	-93.75397	Female	C13	NW	
CAN004126	NWON	48.80331	-93.82417	Male	C13	NW	4
CAN004127	NWON	48.63110	-93.69204		C99	NW	
CAN004128	NWON	48.57893	-93.60200	Male	C99	NW	
CAN004129	NWON	48.68772	-93.42737	Female	C98	NW	
CAN004130	NWON	48.66674	-93.45312	Female	C99	NW	
CAN004131	NWON	48.66960	-93.39685	Male	C98	NW	1
CAN004132	NWON	48.71157	-93.40448	Male	C98	NW	1
CAN004134	NWON	48.71157	-93.46075	Male	C9	NW	1
CAN004135	NWON	48.93760	-91.63971	Female	C13	NW	
CAN004136	NWON	48.75924	-91.62875	Male	C3	NW	4
CAN004137	NWON	48.79678	-91.68006	Male	C13	NW	4
CAN004138	NWON	48.81243	-91.66606	Male	C13	NW	4
CAN004139	NWON	48.84750	-91.79764	Male	C22	OW	2
CAN004140	NWON	48.85949	-91.78222	Male	C3	NW	4
CAN004141	NWON	48.80981	-91.81221	Female	C13	NW	
CAN004142	NWON	48.78925	-91.80450	Male	C13	NW	2
CAN004145	NWON	49.81354	-92.97188	Female	C22	OW	

Table A1 continued

Sample	Location	Latitude	Longitude	Sex	mtDNA	OW/NW	Y-intron
CAN004146	NWON	49.69242	-91.54933	Male	C13	NW	4
CAN004147	NWON	49.69242	-91.54933	Female	C13	NW	
CAN004148	NWON	49.69242	-91.54933	Male	C13	NW	
CAN004149	NWON	49.64670	-91.70511	Female	C13	NW	
CAN004152	NWON	48.98563	-88.33371		C22	OW	
CAN004153	NWON	48.98335	-88.29357	Female	C22	OW	
CAN004154	NWON	48.98866	-88.37536	Female	C23	OW	
CAN004155	NWON	49.02046	-88.33446	Female	C22	OW	
CAN004156	NWON	48.65584	-88.66439	Female	C22	OW	
CAN004157	NWON	48.77000	-91.60000	Female	C22	OW	
CAN004158	NWON	48.40506	-89.22947	Female	C22	OW	
CAN004159	NWON	48.37081	-89.26834	Male	C22	OW	4
CAN004160	NWON	48.43838	-89.27204	Female	C22	OW	
CAN004161	NWON	48.75000	-91.65000	Male	C22	OW	4
CAN004162	NWON	48.53100	-88.96700	Female	C22	OW	
CAN004163	NWON	48.54861	-89.14252	Female	C22	OW	
CAN004164	NWON	48.53800	-88.96200	Female	C22	OW	
CAN004165	NWON	48.40876	-89.30073	Male	C13	NW	4
CAN004168	NWON	48.78000	-91.63000	Male	C22	OW	4
CAN004169	NWON	49.42023	-91.60340	Male	C22	OW	4
CAN004171	NWON	48.75149	-91.86040	Female	C3	NW	
CAN004172	NWON	49.08715	-91.53408	Male	C3	NW	4
CAN004173	NWON	49.73263	-86.50777	Male	C22	OW	4
CAN004174	NWON	49.77939	-86.45817	Female	C22	OW	
CAN004175	NWON	49.83182	-86.48651	Female	C22	OW	
CAN004176	NWON	48.67772	-89.49756	Female	C13	NW	
CAN004185	NWON	49.78931	-86.12377	Male	C14	NW	2
CAN004186	NWON	49.76678	-86.46008	Male	C22	OW	2
CAN004467	NWON	49.77509	-94.72068	Male	C23	OW	2
CAN004480	NWON	51.03341	-93.74088	Female	C3	NW	
CAN004481	NWON	51.02502	-93.72829	Female	C3	NW	
CAN004496	NWON	49.80773	-86.61688	Male	C22	OW	2
CAN004611	NWON	49.84104	-86.50176	Female	C22	OW	
CAN004612	NWON	49.78081	-86.53753	Male	C3	NW	2
CAN005260	NWON	48.40139	-89.26778	Female	C3	NW	
CAN003822	MICH	46.57099	-89.23023	Male	C13	NW	2
CAN003823	MICH	46.70180	-88.97907	Male	C13	NW	4
CAN003824	MICH	46.51398	-88.75221	Female	C22	OW	
CAN003825	MICH	46.60039	-88.93908	Male	C13	NW	2
CAN003826	MICH	46.87357	-88.58327	Female	C13	NW	

Table A1 continued

Sample	Location	Latitude	Longitude	Sex	mtDNA	OW/NW	Y-intron
CAN003827	MICH	46.54288	-90.29069	Female	C13	NW	
CAN003828	MICH	46.19604	-87.91890	Female	C22	OW	
CAN003829	MICH	46.19604	-87.91890	Male	C22	OW	2
CAN003830	MICH	46.25394	-88.16943	Male	C22	OW	2
CAN003831	MICH	46.25394	-88.16943	Male	C3	NW	2
CAN003832	MICH	46.62909	-88.45998	Male	C13	NW	4
CAN003833	MICH	46.32592	-88.35653	Male	C3	NW	4
CAN003834	MICH	46.13648	-84.78938	Female	C13	NW	
CAN003835	MICH	46.23940	-88.37725	Male	C3	NW	4
CAN003836	MICH	46.16712	-87.98182	Male	C13	NW	4
CAN003837	MICH	46.28247	-88.35665	Male	C22	OW	2
CAN003838	MICH	45.96222	-86.58328	Female	C13	NW	
CAN003839	MICH	45.94796	-86.66822	Male	C97	OW	4
CAN003840	MICH	46.41233	-89.48046	Male	C22	OW	2
CAN003841	MICH	46.57103	-90.02069	Female	C13	NW	
CAN003842	MICH	46.12236	-85.45717	Male	C3	NW	2
CAN003843	MICH	46.57103	-90.02069	Female	C13	NW	
CAN003844	MICH	46.58556	-90.04163	Male	C13	NW	2
CAN003845	MICH	46.52833	-88.81493	Male	C22	OW	4
CAN003846	MICH	46.13812	-88.93899	Female	C13	NW	
CAN003847	MICH	46.55698	-88.96056	Female	C22	OW	
CAN003848	MICH	46.34034	-89.87537	Female	C22	OW	
CAN003849	MICH	46.34041	-88.77260	Female	C3	NW	
CAN003850	MICH	46.46998	-89.79256	Male	C22	OW	2
CAN003851	MICH	46.46998	-89.79256	Male	C3	NW	4
CAN003852	MICH	46.46998	-89.79256	Female	C22	OW	
CAN003853	MICH	46.38395	-88.56459	Male	C3	NW	4
CAN003854	MICH	46.09432	-87.66858	Female	C13	NW	
CAN003855	MICH	46.67212	-89.81262	Male	C22	OW	2
CAN003856	MICH	46.67212	-89.81262	Male	C97	OW	2
CAN003857	MICH	46.55635	-89.41705	Male	C22	OW	2
CAN003858	MICH	46.21041	-88.66880	Female	C3	NW	
CAN003859	MICH	46.21040	-88.62698	Male	C3	NW	4
CAN003860	MICH	46.09461	-88.77263	Female	C3	NW	
CAN003861	MICH	46.21037	-88.87629	Female	C22	OW	
CAN003862	MICH	46.54290	-90.20805	Female	C22	OW	
CAN003863	MICH	46.23820	-85.24823	Female	C22	OW	
CAN003864	MICH	46.55692	-90.12414	Male	C22	OW	4
CAN003865	MICH	46.64381	-90.12386	Female	C13	NW	
CAN003866	MICH	46.03570	-86.93420	Male	C13	NW	4

Table A1 continued

Sample	Location	Latitude	Longitude	Sex	mtDNA	OW/NW	Y-intron
CAN003867	MICH	46.47014	-89.60485	Male	C22	OW	2
CAN003868	MICH	46.42649	-89.45982	Female	C22	OW	
CAN003869	MICH	46.10000	-87.65000	Female	C13	NW	
CAN003870	MICH	46.52801	-88.96067	Male	C22	OW	2
CAN003871	MICH	46.54248	-88.96072	Male	C22	OW	2
CAN003872	MICH	46.15000	-85.65000	Male	C22	OW	2
CAN003873	MICH	46.17627	-85.65700	Male	C22	OW	2
CAN004874	MICH	46.68652	-88.60528	Male	C13	NW	4
CAN004875	MICH	46.91725	-88.22449	Male	C22	OW	2
CAN004876	MICH	46.80102	-88.58304	Female	C13	NW	
CAN004877	MICH	46.93111	-88.77389	Male	C13	NW	2
CAN004878	MICH	46.09415	-88.39823	Male	C13	NW	2
CAN004879	MICH	46.09401	-85.31003	Male	C13	NW	4
CAN004880	MICH	46.43983	-85.95888	Male	C13	NW	
CAN004881	MICH	46.16549	-86.12597	Female	C13	NW	
CAN004882	MICH	46.18010	-86.14695	Male	C3	NW	4
CAN004883	MICH	46.35327	-86.20964	Male	C13	NW	4
CAN004884	MICH	46.62909	-88.46003		C13	NW	
CAN004885	MICH	46.00733	-87.75227	Male	C22	OW	
CAN004886	MICH	46.87352	-88.64689	Male	C13	NW	
CAN004887	MICH	46.04941	-84.78929	Male	C13	NW	
CAN004888	MICH	46.19484	-85.33134	Female	C13	NW	
CAN004889	MICH	46.04941	-84.78929	Male	C13	NW	
CAN004890	MICH	46.12236	-85.45711	Male	C22	OW	
CAN004891	MICH	46.04941	-84.78929		C13	NW	
CAN004892	MICH	46.22378	-85.47742	Male	C13	NW	
CAN004893	MICH	46.03558	-85.06104	Male	C1	NW	
CAN004894	MICH	46.22360	-85.51926		C22	OW	
CAN004895	MICH	46.18029	-85.66564		C13	NW	
CAN004896	MICH	46.74430	-87.95970		C22	OW	
CAN004897	MICH	46.35289	-86.10466	Male	C13	NW	4
CAN004898	MICH	46.25243	-84.64470		C97	OW	
CAN004899	MICH	45.87547	-84.81011	Male	C13	NW	2
CAN004900	MICH	45.99037	-86.02217	Male	C3	NW	
CAN004901	MICH	45.25201	-87.48082		C3	NW	
CAN004902	MICH	45.71727	-87.27420	Male	C96	OW	2
CAN004903	MICH	46.19474	-85.56096		C13	NW	
CAN004904	MICH	46.13703	-85.53995		C3	NW	
CAN004905	MICH	46.13703	-85.53995		C13	NW	
CAN004906	MICH	45.74626	-87.13124		C22	OW	

Table A1 continued

Sample	Location	Latitude	Longitude	Sex	mtDNA	OW/NW	Y-intron
CAN004907	MICH	45.77540	-87.11058		C97	OW	
CAN004908	MICH	45.93480	-87.29481	Male	C3	NW	4
CAN004909	MICH	45.99301	-87.77309		C22	OW	
CAN004910	MICH	46.77234	-88.73144		C13	NW	
CAN004911	MICH	47.06186	-88.39377	Female	C13	NW	
CAN004912	MICH	46.15154	-86.91769	Female	C22	OW	
CAN004913	MICH	46.26644	-86.16789	Male	C22	OW	4
CAN004914	MICH	46.06558	-88.00260		C3	NW	
CAN004915	MICH	46.88800	-88.62576		C13	NW	
CAN004916	MICH	46.88800	-88.62576		C13	NW	
CAN004917	MICH	46.88800	-88.62576	Male	C13	NW	
CAN004918	MICH	46.29526	-85.93787	Male	C13	NW	
CAN004919	MICH	46.09336	-85.47819	Male	C14	NW	
CAN004920	MICH	46.47020	-87.54074	Male	C22	OW	
CAN004921	MICH	46.17966	-84.37378	Male	C22	OW	
CAN004922	MICH	45.99298	-88.39824	Male	C13	NW	2
CAN004923	MICH	46.61456	-87.68731	Female	C22	OW	
CAN004924	MICH	46.78661	-88.54100	Male	C13	NW	2
CAN004925	MICH	46.12210	-84.37360	Female	C13	NW	
CAN004926	MICH	46.58608	-88.43922	Male	C13	NW	2
CAN004927	MICH	46.02095	-84.87311	Male	C13	NW	2
CAN004928	MICH	45.55841	-87.33751	Male	C97	OW	2
CAN004929	MICH	46.77219	-88.68924	Male	C13	NW	2
CAN004930	MICH	46.65759	-88.48034	Male	C13	NW	2
CAN004931	MICH	46.98948	-88.41457	Female	C13	NW	
CAN004932	MICH	46.03653	-88.33567	Female	C97	OW	
CAN005268	MICH	46.20830	-84.64497	Male	C19	NW	1
CAN005269	MICH	46.21216	-84.65123	Female	C9	NW	
CAN005270	MICH	46.20508	-84.63996	Female	C13	NW	
CAN004864	WISC	45.75589	-90.22036	Male	C97	OW	4
CAN004865	WISC	45.95630	-89.39825	Female	C48	NW	
CAN004866	WISC	46.19920	-91.03620	Male	C9	NW	1
CAN004933	WISC	46.05000	-90.10000	Male	C22	OW	4
CAN004934	WISC	45.70000	-89.85000	Female	C22	OW	
CAN004935	WISC	45.52815	-90.37272	Female	C13	NW	
CAN004936	WISC	44.56310	-89.67810		C3	NW	
CAN004937	WISC	44.00230	-90.47720		C22	OW	
CAN004938	WISC	46.14685	-90.41134	Male	C22	OW	2
CAN004939	WISC	43.60000	-90.00000	Male	C3	NW	4
CAN004940	WISC	46.30130	-90.40490	Female	C22	OW	

Table A1 continued

Sample	Location	Latitude	Longitude	Sex	mtDNA	OW/NW	Y-intron
CAN004941	WISC	45.91220	-90.87570	Female	C22	OW	
CAN004942	WISC	46.32722	-90.61514	Male	C22	OW	4
CAN004943	WISC	44.20000	-90.60000	Male	C13	NW	2
CAN004944	WISC	44.93000	-91.42800	Female	C13	NW	
CAN004945	WISC	45.80752	-88.26852	Male	C3	NW	2
CAN004946	WISC	46.09950	-91.71917	Male	C13	NW	2
CAN004947	WISC	44.88550	-89.18640	Female	C13	NW	
CAN004948	WISC	46.09989	-91.76783	Male	C13	NW	
CAN004949	WISC	44.80000	-88.90000	Female	C13	NW	
CAN004950	WISC	44.35000	-90.60000	Male	C3	NW	4
CAN004951	WISC	43.19843	-89.81095		C13	NW	
CAN004952	WISC	46.65000	-91.50000	Female	C23	OW	
CAN004953	WISC	44.13128	-91.24807	Female	C13	NW	
CAN004954	WISC	43.15000	-90.35000	Male	C23	OW	2
CAN004955	WISC	45.50000	-89.75000	Male	C22	OW	2
CAN004956	WISC	45.58300	-90.60202	Male	C3	NW	4
CAN004957	WISC	45.58834	-90.60202	Female	C3	NW	
CAN004958	WISC	45.46654	-91.54338	Female	C13	NW	
CAN004959	WISC	45.59140	-90.60955	Female	C3	NW	
CAN004960	WISC	45.58783	-90.60718	Female	C3	NW	
CAN004961	WISC	46.74019	-91.35629	Male	C13	NW	4
CAN004962	WISC	46.62271	-92.04132	Female	C13	NW	
CAN004963	WISC	46.65288	-91.65999	Male	C13	NW	2
CAN004964	WISC	46.66054	-91.69141	Female	C13	NW	
CAN004965	WISC	46.66054	-91.69141	Male	C22	OW	2
CAN004966	WISC	46.64358	-91.86640	Male	C13	NW	4
CAN004967	WISC	46.64098	-91.86645	Male	C13	NW	4
CAN004968	WISC	46.64090	-91.86308	Female	C13	NW	
CAN004969	WISC	46.46122	-91.86450	Male	C5	NW	1
CAN004970	WISC	46.68782	-91.68669	Male	C13	NW	2
CAN004971	WISC	46.68782	-91.68669	Male	C13	NW	2
CAN004972	WISC	46.65776	-91.68655	Male	C19	NW	2
CAN004973	WISC	46.62832	-91.91911	Male	C13	NW	4
CAN004974	WISC	46.62731	-91.91644	Male	C13	NW	4
CAN004975	WISC	46.64098	-91.86308	Male	C19	NW	1
CAN004976	WISC	45.78733	-89.87878	Female	C97	OW	
CAN005261	WISC	45.50000	-92.50000		C13	NW	
CAN004815	MINN	48.35249	-93.45473	Female	C13	NW	
CAN004816	MINN	48.35249	-93.45473	Male	C3	NW	4
CAN004817	MINN	48.35249	-93.45473	Male	C13	NW	4

Table A1 continued

Sample	Location	Latitude	Longitude	Sex	mtDNA	OW/NW	Y-intron
CAN004818	MINN	48.35249	-93.45473	Female	C22	OW	
CAN004819	MINN	48.30243	-95.32564	Male	C13	NW	2
CAN004820	MINN	48.30243	-95.32564	Female	C13	NW	
CAN004821	MINN	48.67769	-94.28900	Male	C3	NW	4
CAN004822	MINN	47.95484	-94.40743	Male	C3	NW	4
CAN004823	MINN	48.67769	-94.28900	Male	C22	OW	4
CAN004824	MINN	47.95484	-94.40743	Female	C3	NW	
CAN004825	MINN	47.27664	-92.63124	Female	C22	OW	
CAN004826	MINN	47.27664	-92.63124	Male	C22	OW	2
CAN004827	MINN	47.27664	-92.63124	Male	C22	OW	2
CAN004828	MINN	46.29593	-92.98026	Male	C13	NW	4
CAN004829	MINN	46.61595	-93.39070	Male	C13	NW	2
CAN004830	MINN	48.63374	-95.14800	Male	C3	NW	
CAN004831	MINN	46.92512	-94.13605	Male	C22	OW	2
CAN004832	MINN	46.88864	-94.10805	Female	C22	OW	
CAN004833	MINN	46.92307	-94.11063	Male	C22	OW	2
CAN004834	MINN	48.45250	-95.40706	Male	C22	OW	2
CAN004835	MINN	48.49827	-94.82087	Male	C3	NW	4
CAN004836	MINN	48.52995	-94.98335	Female	C3	NW	
CAN004837	MINN	48.72410	-95.24172	Female	C3	NW	
CAN004838	MINN	48.72025	-95.06407	Male	C23	OW	2
CAN004839	MINN	48.56072	-95.34353	Female	C3	NW	
CAN004840	MINN	47.20474	-93.69366	Male	C3	NW	2
CAN004841	MINN	47.20407	-93.69417	Male	C3	NW	2
CAN004842	MINN	47.05769	-93.62068	Male	C13	NW	2
CAN004843	MINN	48.02916	-92.81947	Female	C22	OW	
CAN004844	MINN	46.93789	-92.93045	Female	C13	NW	
CAN004845	MINN	48.12322	-96.18299	Male	C13	NW	4
CAN004846	MINN	45.29190	-93.46016	Female	C13	NW	
CAN004847	MINN	47.42330	-91.98358	Female	C3	NW	
CAN004848	MINN	46.03290	-93.84191	Female	C3	NW	
CAN004849	MINN	46.03290	-93.84191	Male	C3	NW	4
CAN004850	MINN	46.03290	-93.84191	Male	C3	NW	4
CAN004851	MINN	46.03290	-93.84191	Female	C3	NW	
CAN004852	MINN	48.25886	-95.25988	Male	C13	NW	2
CAN004853	MINN	48.25886	-95.25988	Female	C3	NW	
CAN004854	MINN	48.89732	-96.76624	Female	C3	NW	
CAN004855	MINN	48.96974	-96.76728	Male	C3	NW	2
CAN004856	MINN	47.46243	-95.45625	Female	C22	OW	

Table A1 continued

Sample	Location	Latitude	Longitude	Sex	mtDNA	OW/NW	Y-intron
CAN004857	MINN	47.46243	-95.45625	Male	C13	NW	2
CAN004858	MINN	47.89782	-95.52710	Male	C13	NW	4
CAN004859	MINN	47.73909	-95.78399	Male	C22	OW	2
CAN004860	MINN	47.73909	-95.78399	Male	C13	NW	2
CAN004861	MINN	48.67769	-94.28900	Female	C3	NW	
CAN004862	MINN	48.67769	-94.28900	Female	C22	OW	
CAN004863	MINN	47.84765	-93.49913	Female	C3	NW	
CAN005256	MINN	46.28000	-92.63000	Female	C72	NW	
CAN005257	MINN	46.20000	-92.63000	Male	C19	NW	1
CAN005258	MINN	46.12000	-92.80000	Male	C9	NW	2
CAN005259	MINN	46.37000	-92.44000	Female	C70	NW	

Table A2: Summary of mtDNA and Y-intron haplotype frequencies by state/region.

Haplotype	Sequence type	Total	MN	WI	MI	NWON	NEON
C1	New World mtDNA	3			1		2
C3	New World mtDNA	70	21	8	16	22	3
C5	New World mtDNA	1		1			
C9	New World mtDNA	16	1	1	1	1	12
C13	New World mtDNA	121	14	22	52	25	8
C14	New World mtDNA	24			1	1	22
C17	New World mtDNA	2					2
C19	New World mtDNA	13	1	2	1		9
C48	New World mtDNA	1		1			
C70	New World mtDNA	1	1				
C72	New World mtDNA	1	1				
C98	New World mtDNA	3				3	
C99	New World mtDNA	4				3	1
C22	Old World mtDNA	114	13	9	35	32	25
C23	Old World mtDNA	19	1	2		4	12
C95	Old World mtDNA	2				1	1
C96	Old World mtDNA	1			1		
C97	Old World mtDNA	8		2	6		
CANInt1	ancestral Y-intron	13	1	3	1	3	5
CANInt2	gray wolf Y-intron	106	17	11	30	16	32
CANInt4	eastern wolf Y-intron	74	11	11	19	24	9

Table A3: Raw microsatellite genotype data of canid samples used in STRUCTURE and FCA analyses. Locations: APP = Algonquin Provincial Park; FRAX = Frontenac Axis; HIST = Historic; MB = Manitoba; MI = Michigan; MN = Minnesota; NEON = northeastern Ontario; NWON = northwestern Ontario; NWT = Northwest Territories; QUE = Quebec; TX = Texas; WI = Wisconsin.

Sample	Location	cxx225		cxx200		cxx123		cxx377		cxx250		cxx204		cxx172		cxx109		cxx253		cxx442		cxx410		cxx147	
CAN004249	APP	163	167	215	217	149	151	154	162	135	139	200	200	144	156	143	143	109	117	160	168	96	114	168	172
CAN004250	APP	167	167	217	221	147	153	154	166	133	135	200	200	144	158	143	145	103	105	166	166	98	118	172	174
CAN004253	APP	167	167	211	221	149	153	156	160	133	135	200	200	154	154	143	143	113	117	166	166	114	114	172	176
CAN004255	APP	167	179	207	213	149	149	154	164	135	135	200	202	154	154	143	145	117	117	164	166	114	114	168	172
CAN004261	APP	171	179	215	221	143	147	154	156	135	139	200	202	154	158	143	143	103	109	160	162	114	120	174	176
CAN004262	APP	167	167	215	221	147	153	144	154	135	141	200	200	158	160	143	151	109	109	166	166	98	118	172	176
CAN004263	APP	167	179	211	211	147	149	154	174	139	139	212	214	158	158	143	149	107	111	162	164	98	118	168	172
CAN004264	APP	165	165	213	217	149	149	154	162	135	135	200	206	154	154	143	145	113	117	160	164	114	118	168	168
CAN004269	APP	163	167	207	217	149	153	154	156	135	135	200	202	158	160	143	143	109	113	160	166	98	114	168	172
CAN004273	APP	167	169	215	217	149	153	154	162	135	139	200	200	154	154	143	143	117	117	166	168	102	114	172	176
CAN004279	APP	165	167	215	221	149	153	154	160	131	135	200	200	144	158	143	143	103	105	160	164	114	114	168	176
CAN004280	APP	169	171	205	205	145	147	154	154	135	135	200	202	144	158	143	145	105	109	160	166	98	114	168	172
CAN004281	APP	163	167	205	213	145	149	154	160	135	135	200	200	160	160	143	143	105	109	160	160	114	114	172	172
CAN004282	APP	167	179	207	215	149	149	160	166	135	143	200	200	144	144	143	143	113	117	166	166	114	114	168	172
CAN004284	APP	167	167	215	221	147	147	154	164	135	135	200	200	158	160	143	143	103	105	160	164	114	114	172	172
CAN004286	APP	167	171	205	215	147	149	154	160	135	137	200	200	144	158	149	155	103	105	164	164	114	116	168	176
CAN004290	APP	163	167	209	213	147	149	154	154	131	135	200	206	154	160	143	155	117	117	164	166	96	114	172	176
CAN004292	APP	163	163	215	215	147	153	154	154	135	137	200	200	154	160	143	145	105	109	166	166	114	114	172	174
CAN004293	APP	167	167	211	217	149	153	144	154	135	141	200	200	160	160	143	143	105	117	166	166	98	112	172	176
CAN004297	APP	165	167	213	215	149	149	154	154	135	145	200	206	154	154	143	151	103	113	160	160	98	114	168	172
CAN004298	APP	163	165	211	217	147	149	146	162	135	137	200	200	144	158	143	143	103	117	160	166	98	114	168	176
CAN004299	APP	165	167	205	217	147	153	154	170	137	139	200	200	160	160	143	151	103	107	164	166	114	118	172	176
CAN004309	APP	167	167	215	221	147	153	144	154	135	141	200	200	158	160	143	143	105	109	164	172	98	112	170	172
CAN004310	APP	167	167	217	217	149	149	164	164	133	135	200	200	144	144	143	143	103	109	160	160	96	118	168	172
CAN004313	APP	167	167	215	221	147	153	154	156	135	141	200	200	154	160	143	143	105	117	166	166	118	118	170	176
CAN004314	APP	163	167	215	215	147	147	154	164	135	141	200	200	144	154	143	149	117	117	162	166	98	114	178	178
CAN004316	APP	167	179	213	221	149	149	154	164	135	135	200	206	154	154	143	145	105	117	166	166	114	114	168	172
CAN004324	APP	165	167	215	221	147	149	154	156	135	135	200	200	160	160	143	143	103	105	160	160	114	114	168	172

Table A3 continued

Sample	Location	cxx225		cxx200		cxx123		cxx377		cxx250		cxx204		cxx172		cxx109		cxx253		cxx442		cxx410		cxx147	
CAN004333	APP	167	167	215	215	147	149	144	156	135	135	200	200	154	160	143	143	105	105	160	166	114	116	168	176
CAN004339	APP	165	167	215	215	149	153	144	154	135	137	200	206	154	158	143	151	105	117	164	166	98	114	170	176
CAN004361	APP	167	167	211	215	147	149	154	160	133	143	200	200	158	158	143	143	103	107	160	164	114	114	172	172
CAN004364	APP	167	171	213	217	147	147	162	174	131	135	200	202	158	160	143	151	105	109	160	160	114	120	172	176
CAN004367	APP	163	169	205	215	143	143	162	162	131	137	200	202	144	144	143	143	109	117	160	168	98	114	168	172
CAN004372	APP	167	167	217	221	143	147	154	154	135	135	200	200	144	158	143	149	113	117	160	164	98	114	168	174
CAN004373	APP	163	165	215	215	143	153	154	156	139	141	200	200	144	154	143	143	109	117	166	166	114	114	178	178
CAN004377	APP	167	167	205	207	147	153	154	166	135	145	200	206	144	144	143	151	117	117	162	166	98	98	168	174
CAN004378	APP	167	169	205	205	145	147	154	160	135	135	200	202	144	158	143	149	105	109	164	166	114	114	168	176
CAN004379	APP	165	167	211	215	153	153	154	154	135	137	200	200	154	160	143	143	117	117	166	166	112	114	172	176
CAN004382	APP	167	167	211	211	147	149	156	162	131	135	202	206	156	156	149	151	107	113	168	172	114	114	172	172
CAN004423	APP	167	167	221	227	147	149	154	160	133	135	200	200	144	158	143	151	103	105	164	166	114	114	168	172
CAN004434	APP	179	179	213	217	149	149	154	154	135	139	200	200	154	158	143	143	103	117	162	166	112	114	168	172
CAN004436	APP	163	167	221	221	149	153	156	168	131	139	200	214	158	158	143	143	103	105	164	166	116	118	172	176
CAN004437	APP	167	167	215	215	143	153	154	154	137	137	202	208	144	154	143	143	109	117	166	166	114	114	172	174
CAN004440	APP	165	167	215	215	147	147	154	154	139	139	200	200	154	158	143	143	113	117	160	166	114	116	174	178
CAN004441	APP	163	163	211	221	147	153	146	164	133	135	200	200	144	144	143	143	103	103	166	166	98	114	168	168
CAN004443	APP	163	167	207	215	143	147	146	164	137	139	200	202	144	144	151	151	117	117	160	160	98	98	168	172
CAN004444	APP	169	177	211	221	147	149	156	156	135	135	200	200	144	154	145	151	113	117	162	164	114	114	172	176
CAN004445	APP	165	177	213	215	149	149	162	174	135	135	200	200	158	158	143	145	103	105	160	160	98	114	176	176
CAN004447	APP	163	169	207	215	147	149	146	154	135	139	200	200	154	156	143	143	109	113	166	166	114	114	172	176
CAN004448	APP	163	165	215	215	147	153	164	164	139	141	200	200	144	154	143	143	109	117	162	166	98	114	168	178
CAN004450	APP	167	167	211	221	145	149	154	166	135	139	200	200	154	158	143	143	105	117	166	168	98	112	168	178
CAN004451	APP	163	165	217	217	147	149	154	156	135	135	200	200	156	158	143	145	103	107	164	164	114	114	170	174
CAN004454	APP	167	167	213	213	149	149	164	164	131	135	200	202	144	154	143	145	117	117	164	166	114	114	168	172
CAN004455	APP	167	167	215	217	147	149	154	162	135	139	200	200	158	160	143	145	109	117	160	166	114	116	168	178
CAN000274	FRAX	169	179	207	211	149	149	154	166	131	135	200	200	144	144	143	151	109	115	160	166	98	114	168	172
CAN000276	FRAX	167	167	215	215	147	147	154	154	131	135	200	202	144	158	143	149	103	111	166	172	114	122	172	172
CAN000277	FRAX	165	179	211	221	147	149	156	164	135	139	200	200	160	160	143	151	105	111	160	172	112	118	172	172
CAN000278	FRAX	179	179	221	221	147	153	164	166	135	141	200	200	144	160	143	147	111	111			98	120		
CAN000279	FRAX	167	179	211	211	147	149	166	174	139	139	200	202	144	158	143	151	113	115	160	160	98	114	168	172
CAN000280	FRAX	167	167	211	215	149	149	154	174	135	139	200	202	158	160	143	151	111	115	160	164	98	114		

Table A3 continued

Sample	Location	cxx225		cxx200		cxx123		cxx377		cxx250		cxx204		cxx172		cxx109		cxx253		cxx442		cxx410		cxx147	
CAN000283	FRAX	179	179	207	211	143	143	156	166	141	145	200	202	144	158	143	151	105	105	166	166	98	114	172	172
CAN000284	FRAX	171	179	209	217	149	149	160	166	139	145	200	202	144	154	149	151	107	111	160	168	118	122		
CAN000286	FRAX	163	179	215	221	147	149	166	176	137	139	200	200	144	160	143	151	105	105	168	168	112	114	172	172
CAN000288	FRAX	167	167	215	221	153	153	154	154	135	137	200	206	154	158	143	145	105	117	166	168	114	118	170	176
CAN000289	FRAX	179	179	207	211	153	153	166	166	133	135	200	200	144	160	151	153	107	117	160	160	112	122	172	174
CAN000291	FRAX	163	167	207	215	147	149	160	174	131	139	200	200	158	158	151	151	111	115	166	168	114	114		
CAN000292	FRAX	179	179	217	227	147	147	162	162	139	145	200	200	144	160	143	155	113	117	164	172	112	122		
CAN000293	FRAX	165	177	207	211	149	149	154	162	135	135	200	200	158	160	143	151	103	105	166	168	98	114	172	172
CAN000294	FRAX	179	179	215	217	149	149	166	166	139	145	200	206	144	144	143	143	103	117	166	166	112	118	176	176
CAN000295	FRAX	165	167	211	221	147	149	156	166	131	141	200	202	156	158	151	151	105	115	162	166	98	118		
CAN000298	FRAX	163	167	209	211	147	149	174	174	129	139	200	202	158	160	145	151	111	117	164	164	98	122	168	172
CAN000301	FRAX	167	179	209	211	149	149	154	162	139	141	200	200	158	160	151	151	117	117	160	172	98	110	172	176
CAN000302	FRAX	169	179	207	211	149	149	162	174	137	139	200	200	158	160	151	151	105	113	160	164	112	114		
CAN000512	FRAX	165	165	209	215	147	149	166	166	139	141	200	200	158	158	151	153	103	115			98	114		
CAN000516	FRAX	167	179	215	217	149	149	154	166	135	139	200	200	144	158	143	151	105	113	160	168	114	116	176	176
CAN000517	FRAX	167	179	217	227	149	149	154	160	135	139	200	202	144	160	147	151	105	111	164	168	98	114	172	172
CAN000518	FRAX	169	169	209	217	143	147	154	166	135	145	200	202	158	160	143	143	109	111	166	168	112	114	172	172
CAN000520	FRAX	169	179	207	215	147	147	162	166	139	145	202	202	144	154	151	155	103	117	160	168	112	122	172	176
CAN000521	FRAX	169	179	207	209	149	149	166	166	131	131	200	202	156	158	143	153	103	105	160	164	114	122	168	172
CAN000522	FRAX	167	179	207	221	147	149	156	164	139	139	200	202	144	144	151	151	103	105	166	166	118	122	168	172
CAN000523	FRAX	167	177	215	221	143	147	154	158	131	135	200	202	144	144	149	155	103	113	160	166	98	122	172	172
CAN000524	FRAX	177	179	207	215	147	149	154	162	133	135	200	200	144	160	143	147	111	117	166	172	98	112	168	168
CAN000525	FRAX	169	179	209	215	149	149	166	166	135	139	200	202	158	160	147	151	105	117	160	160	114	122		
CAN000526	FRAX	169	179	207	221	147	147	162	166	135	145	200	202	144	154	143	155	105	117			112	114		
CAN000527	FRAX	169	177	209	215	147	149	162	166	139	139	200	202	144	144	143	143	109	115	160	168	114	122	168	176
CAN000529	FRAX	167	179	207	211	147	147	166	166	137	137	200	200	144	144	153	153	103	103	168	168	118	122	168	172
CAN000530	FRAX	171	179	207	211	147	147	156	166	137	141	200	202	144	160	143	153	103	111	164	168	114	118	168	168
CAN000531	FRAX	167	169	215	221	149	149	144	162	135	135	200	202	154	154	143	145	109	109	166	168	98	118	172	176
CAN000532	FRAX	165	171	211	213	147	149	154	174	143	145	200	200	144	160	151	153	103	113	160	172	110	122	172	176
CAN000533	FRAX	167	167	207	221	147	149	166	174	135	137	200	200	158	160	149	149	103	113	164	172	98	98	172	172
CAN000535	FRAX	169	169	209	227	147	147	162	162	131	139	200	200	144	160	143	147	111	117	164	166	98	114	172	176
CAN000537	FRAX	165	179	221	221	149	149	154	162	133	139	200	200	144	160	143	145	105	117	160	166	98	114		

Table A3 continued

Sample	Location	cxx225		cxx200		cxx123		cxx377		cxx250		cxx204		cxx172		cxx109		cxx253		cxx442		cxx410		cxx147	
CAN000540	FRAX	177	179	209	221	149	149	154	154	133	139	200	202	158	160	145	145	105	117	166	166	98	114	176	176
CAN000541	FRAX	167	177	215	221	147	153	162	166	133	135	200	214	160	160	147	153	115	115	160	166	98	112	168	172
CAN000542	FRAX	165	179	207	215	149	149	166	166	139	141	200	200	144	160	143	143	115	117	164	166	98	118	168	176
CAN000543	FRAX	163	167	207	221	149	153	150	162	137	139	200	214	160	160	147	151	113	115	168	172	98	114	168	176
CAN000545	FRAX	167	167	221	221	147	153	166	176	135	139	200	200	144	158	147	151	105	111	164	166	114	118	172	176
CAN000548	FRAX	163	179	211	215	147	149	166	166	135	137	200	200	144	144	143	143	109	109	162	166	112	116		
CAN000549	FRAX	167	179	215	221	149	149	166	166	133	139	200	200	158	160	143	149	105	111	160	168	114	114	172	174
CAN000550	FRAX	177	179	215	217	149	149	166	166	135	135	200	202	144	154	151	155	115	117	160	160	98	114	168	172
CAN000553	FRAX	165	167	211	211	149	153	154	174	131	135	200	202	158	160	143	149	103	117	166	166	114	118	172	176
CAN000554	FRAX	163	169	219	219	147	147	150	156	139	141	200	200	144	158	147	147	107	109	160	160	98	114		
CAN000555	FRAX	163	167	209	209	149	149	154	176	135	139	200	200	158	160	147	153	103	111	164	172	112	118	168	176
CAN000556	FRAX	179	179	219	227	149	149	162	174	139	141	200	200	158	160	143	151	115	117	162	164	110	122		
CAN000557	FRAX	179	179	217	219	149	153	146	174	137	139	200	200	144	160	151	153	109	117	160	166	98	112	172	172
CAN000558	FRAX	171	179	211	215	147	149	162	166	145	145	200	200	144	160	151	155	103	111	160	172	110	122	168	172
CAN004459	HIST	165	167	215	217	153	153	156	160	133	135	200	200	154	158	143	149	107	111	164	166	98	124	172	176
CAN004460	HIST	167	167	215	217	149	153	156	164	137	143			154	156			109	117			116	124		
CAN004461	HIST	165	169	215	217	147	149	154	164	131	133	200	206	158	158	143	143	109	109	160	164	98	118	170	174
CAN001316	MB	169	169	211	217	143	153	160	160	135	135	202	202	158	158	143	143	107	109	164	166	98	124	172	172
CAN001319	MB	165	169	211	217	145	153	158	164	137	137	200	206	156	158	149	149	103	103	160	160	124	124	172	176
CAN001320	MB	165	169	217	221	143	143	164	164	137	137	208	208	144	158	143	149	103	109	160	160	98	124	172	172
CAN001321	MB	165	169	211	221	143	143	164	164	133	135	200	200	156	156	143	149	107	107	164	164	114	124	172	172
CAN001322	MB	165	169	211	221	143	153	160	162	137	137	200	202	158	160	143	149	103	109	160	160	124	124	172	172
CAN001323	MB	165	169	211	217	153	153	162	164	135	137	200	208	158	160	149	149	107	109	160	160	98	124	172	176
CAN001326	MB	163	167	211	217	153	153	164	164	133	137	200	200	158	158	149	149	109	117	160	160	98	100	172	172
CAN001327	MB	167	169	211	223	149	153	160	162	133	137	202	202	156	158	143	151	109	109	164	166	114	118	172	172
CAN001335	MB	165	169	211	221	143	153	162	164	135	137	200	202	156	160	147	149	103	107	160	160	98	124	172	176
CAN001336	MB	165	169	211	217	143	149	164	164	133	145	200	200	158	158	143	149	103	109	160	160	98	124	172	176
CAN001337	MB	165	165	217	223	145	153	162	162	133	133	200	206	158	158	143	149	107	109	166	166	98	114	172	172
CAN001338	MB	163	165	223	223	147	151	154	162	133	137	200	202	156	158	147	153	103	107	160	166	114	114	172	176
CAN001339	MB	163	169	217	221	143	143	154	164	135	145	200	200	158	158	143	153	109	109			114	118		
CAN001342	MB	163	167	215	217	145	153	144	154	133	137	200	200	144	158	143	147	109	111	164	164	98	118	172	172
CAN001343	MB	163	169	211	221	143	153	154	154	137	137	202	202	156	156	143	143	109	109	160	164	98	116	172	172

Table A3 continued

Sample	Location	cxx225		cxx200		cxx123		cxx377		cxx250		cxx204		cxx172		cxx109		cxx253		cxx442		cxx410		cxx147	
CAN001344	MB	167	169	223	229	143	153	154	164	145	145	200	206	156	158	143	147	107	109	160	166	98	118	172	172
CAN001348	MB	165	165	217	221	143	143	154	154	133	133	200	200	156	156	143	149	109	117	160	160	98	114	172	176
CAN001349	MB	165	167	211	223	143	153	154	154	137	145	200	200	156	158	143	143	107	109	160	166	114	118	172	172
CAN001350	MB	167	169	211	217	145	149	144	164	135	141	200	206	158	158	143	143	109	117	160	166	118	118	172	172
CAN001351	MB	163	169	215	223	145	151	154	162	135	137	200	200	158	158	147	153	103	109	160	160	114	114	172	172
CAN001358	MB	163	167	217	217	145	145	164	164	135	137	200	206	144	156	143	143	109	109			98	98	172	172
CAN001360	MB	163	169	217	219	143	145	160	160	135	135	200	208	144	156	143	151	109	109	160	160	98	98	172	172
CAN001361	MB	163	163	211	217	143	147	144	162	135	137	200	206	158	158	143	149	109	109	164	166	114	114	172	172
CAN001362	MB	163	169	215	221	143	145	154	162	133	137	206	208	158	158	143	149	111	111	160	164	98	98	172	172
CAN001363	MB	165	167	211	211	143	145	154	162	137	145	202	202	158	158	143	143	107	109	160	164	114	114	172	174
CAN001365	MB	163	163	211	217	153	153	160	164	133	141	200	200	158	158	143	143	107	107	164	164	98	118	172	172
CAN001367	MB	163	169	211	229	145	153	154	162	137	145	200	202	144	158	143	143	107	109	160	160	114	114	172	174
CAN001368	MB	163	167	211	229	143	153	154	154	135	137	200	200	156	158	143	143	107	109	164	166	98	114	168	172
CAN001371	MB	163	167	211	217	153	153	162	164	133	145	200	206	158	158	149	149	109	109	160	160	98	114	170	172
CAN001373	MB	165	169	211	211	153	153	160	162	137	145	200	202	144	160	143	149	103	107	160	160	124	124	172	172
CAN001375	MB	163	167	211	211	143	153	144	158	137	145	200	206	158	158	143	143	103	103	164	164	118	124	172	174
CAN001376	MB	163	165	211	215	143	153	154	164	137	139	202	206	156	156	143	143	109	111	160	160	98	118	172	172
CAN001377	MB	165	169	211	217	143	145	154	162	133	137	200	208	156	158	143	149	103	109	160	160	98	98	172	172
CAN001378	MB	165	167	211	215	149	151	154	154	133	133	202	208	144	158	143	147	109	109	160	160	98	114	172	176
CAN001381	MB	165	169	217	217	143	153	158	164	135	137	200	200	156	160	143	143	103	107	160	164	124	124	172	172
CAN002485	MB	163	163	211	211	143	147	144	154	135	137	206	206	158	158	147	149	109	109	160	166	98	98	172	172
CAN003822	MI	167	167	211	217	153	153	150	154	131	135	200	202	154	154	149	151	103	109	160	166	114	114	172	174
CAN003823	MI	163	167	211	217	143	153	164	164	133	135	202	202	144	158	149	149	103	109	166	166	114	114	170	172
CAN003824	MI	163	169	207	211	143	157	164	164	133	133	200	202	154	156	143	151	105	109	164	166	116	118	172	174
CAN003825	MI	163	169	211	229	153	153	164	164	133	133	200	206	158	158	143	149	107	109	164	166	98	114	172	174
CAN003826	MI	163	169	211	229	143	149	146	164	133	135	200	206	144	158	149	151	109	109	160	166	116	120	172	172
CAN003827	MI	163	163	211	211	147	157	162	164	131	135	200	206	144	156	143	151	109	117	164	166	118	124	172	174
CAN003828	MI	165	169	211	217	147	149	150	156	133	135	200	200	156	158	143	143	109	111	160	164	114	114	168	172
CAN003829	MI	165	165	211	217	153	153	156	160	133	135	200	202	144	156	143	143	109	109	160	160	114	114	172	176
CAN003830	MI	163	163	211	215	147	157	150	164	131	135	200	202	158	160	143	143	109	109	160	166	114	118	170	172
CAN003831	MI	163	163	211	215	143	157	150	160	135	135	200	202	144	160	143	151	109	109	160	166	114	118	170	174
CAN003832	MI	165	167	211	217	143	153	164	170	133	135	200	200	156	158	143	149	107	109	160	166	114	124	172	174

Table A3 continued

Sample	Location	cxx225		cxx200		cxx123		cxx377		cxx250		cxx204		cxx172		cxx109		cxx253		cxx442		cxx410		cxx147	
CAN003833	MI	163	165	211	217	143	147	160	162	135	135	200	200	144	158	143	151	109	117	160	164	114	118	172	174
CAN003834	MI	163	167	211	217	149	153	156	160	133	141	200	206	144	158	143	149	103	109	164	166	116	120	172	174
CAN003835	MI	163	163	205	217	143	147	160	164	133	135	200	200	144	158	143	149	109	109	160	166	116	118	172	174
CAN003836	MI	163	163	211	217	149	153	150	156	135	137	200	200	158	158	143	149	103	117	164	166	114	120	174	174
CAN003837	MI	163	163	217	217	143	153	150	164	135	135	200	200	158	158	143	143	109	109	160	164	114	118	172	174
CAN003838	MI	163	163	211	211	143	153	156	160	133	135	202	202	158	160	143	143	107	109	166	166	114	114	170	174
CAN003839	MI	163	167	211	211	147	157	160	164	133	135	200	200	154	158	143	149	103	109	160	160	114	122	172	174
CAN003840	MI	163	167	217	217	143	153	160	170	131	135	202	202	154	156	143	143	109	111	160	166	114	114	174	174
CAN003841	MI	163	165	211	217	153	157	150	164	131	135	202	202	144	154	143	143	109	117	160	160	98	114	172	172
CAN003842	MI	165	165	205	211	143	147	160	164	135	135	200	200	144	156	143	143	107	111	160	166	98	116	172	174
CAN003843	MI	163	165	205	229	153	157	150	164	131	135	202	202	144	144	143	143	109	109	160	160	116	120	172	174
CAN003844	MI	163	163	205	229	153	157	150	164	131	135	202	202	144	158	143	149	109	109	160	160	114	120	172	174
CAN003845	MI	165	169	211	211	153	157	164	164	133	135	200	202	156	156	143	143	109	109	160	164	114	116	172	172
CAN003846	MI	163	165	211	211	143	149	164	170	133	135	200	200	144	156	143	143	107	109	160	166	116	124	174	174
CAN003847	MI	163	169	217	229	153	153	160	164	133	139	200	200	156	158	143	143	107	109	160	164	98	116	172	174
CAN003848	MI	165	165	211	217	149	157	162	164	135	135	200	200	158	158	143	143	109	111	166	166	114	116	172	172
CAN003849	MI	163	167	211	217	143	153	164	164	135	135	200	200	156	158	141	143	103	111	160	166	114	124	174	174
CAN003850	MI	163	165	211	217	153	153	146	164	133	141	200	212	144	158	143	143	107	111	166	166	98	114	172	174
CAN003851	MI	163	163	211	211	147	153	162	164	135	135	200	200	144	144	143	149	109	109	164	166	114	116	172	174
CAN003852	MI	163	165	211	217	153	153	146	164	133	135	202	212	158	158	143	143	107	111	166	166	114	120	174	174
CAN003853	MI	163	165	211	217	147	153	162	164	133	135	200	200	144	158	143	149	109	109	164	166	114	114	172	174
CAN003854	MI	163	165	211	215	145	149	164	164	133	133	200	200	144	158	143	149	109	109	166	166	114	118	172	172
CAN003855	MI	163	167	217	217	143	153	156	160	131	135	202	206	144	158	143	151	103	109	160	160	116	124	172	174
CAN003856	MI	163	167	217	217	143	153	156	160	135	135	200	206	144	158	143	143	103	109	160	166	114	116	172	172
CAN003857	MI	163	165	211	211	147	147	156	164	135	135	200	200	158	158	143	149	109	109	166	166	114	114	174	174
CAN003858	MI	163	165	205	211	147	153	162	162	133	135	200	200	144	158	143	151	109	117	160	164	114	114	172	174
CAN003859	MI	163	165	211	211	147	153	160	162	133	135	200	202	144	158	143	151	109	109	160	160	114	118	172	174
CAN003860	MI	163	167	211	217	143	157	164	164	133	135	200	202	158	160	141	143	103	109	164	166	114	118	174	174
CAN003861	MI	163	167	211	217	143	153	164	164	135	135	200	202	158	158	149	149	109	111	160	166	114	116	172	174
CAN003862	MI	165	169	211	211	143	153	160	160	131	143	200	200	158	158	141	143	107	109	160	166	124	124	172	172
CAN003863	MI	165	165	211	217	143	153	160	162	135	143	200	200	158	158	141	143	107	109	160	166	124	124	172	174
CAN003864	MI	163	167	211	217	147	153	164	164	135	135	200	206	158	158	141	143	103	117	160	160	114	124	172	174

Table A3 continued

Sample	Location	cxx225		cxx200		cxx123		cxx377		cxx250		cxx204		cxx172		cxx109		cxx253		cxx442		cxx410		cxx147	
CAN003865	MI	165	165	211	217	149	157	160	164	135	135	200	200	158	158	143	143	109	109	160	166	116	118	172	172
CAN003866	MI	167	167	211	211	143	153	154	170	131	135	200	200	144	158	143	149	111	117	160	166	98	124	174	174
CAN003867	MI	163	165	211	229	143	147	160	162	135	141	200	200	144	158	143	143	107	109	166	166	114	120	172	174
CAN003868	MI	163	163	211	215	143	153	164	170	131	135	200	202	144	158	143	143	109	117	160	166	114	114	172	174
CAN003869	MI	163	165	211	217	143	153	160	164	133	135	200	200	144	158	149	151	103	111	166	166	114	118	172	172
CAN003870	MI	163	165	215	217	149	153	146	160	135	139	200	200	154	156	143	149	109	109	160	166	98	114	172	174
CAN003871	MI	165	169	215	229	143	153	146	160	135	139	200	200	158	158	143	149	109	109	160	164	114	116	174	174
CAN003872	MI	163	163	217	217	143	157	150	162	135	141	202	206	156	158	143	143	107	109	160	166	114	118	172	174
CAN003873	MI	163	163	215	217	143	143	160	164	135	135	200	200	144	158	143	143	103	117	164	166	114	116	174	174
CAN004874	MI	165	167	211	211	143	153	156	164	135	135	200	202	144	156	143	143	103	109	160	164	114	114	172	174
CAN004875	MI	163	163	211	217	147	149	150	162	135	135	200	202	158	158	143	149	109	109	166	166	118	120	172	174
CAN004876	MI	163	167	211	211	143	157	162	164	135	135	200	202	160	160	143	151	109	117	160	166	114	124	174	174
CAN004877	MI	163	167	215	217	143	153	154	164	135	135	200	200	154	158	143	151	109	117	160	160	114	114	170	172
CAN004878	MI	165	165	205	211	143	153	160	164	133	135	200	206	144	156	143	143	109	111	166	166	98	114	172	172
CAN004879	MI	163	163	211	211	147	153	156	162	133	135	200	200	144	158	143	151	103	109	160	166	118	120	172	174
CAN004881	MI	163	167	211	211	157	157	160	164	133	135	200	200	154	158	143	151	103	103	160	166	114	114	172	174
CAN004882	MI	163	165	211	211	143	147	162	162	133	135	200	200	144	144	143	151	109	117	164	166	114	118	172	174
CAN004883	MI	165	167	215	217	143	147	160	164	133	135	200	200	144	154	143	143	103	117	160	164	114	114	172	172
CAN004885	MI	163	163			143	153	154	164	135	135	200	202	154	158	141	147	109	109	160	166	114	124	172	172
CAN004888	MI	163	167	211	211	153	157	136	164	131	135	200	202	144	158	143	149	103	109	164	166	98	114	174	174
CAN004892	MI	167	167	211	217	153	153	144	164	133	135	200	202	154	160	143	151	103	109	160	160	114	124	172	172
CAN004897	MI	163	167	211	217	147	147	162	164	133	133	200	202	154	158	143	143	107	109	160	166	118	120	172	172
CAN004899	MI	163	167	211	217	147	149	154	160	133	133	200	206	154	158	143	149	103	107	160	166	98	120	174	174
CAN004902	MI	163	169	211	211	145	145	144	144	137	141	200	200	158	158	143	147	103	117	160	160	114	116	172	176
CAN004908	MI	163	167	211	211	153	153	160	164	133	135	200	200	154	154	143	143	109	109	166	166	114	116	174	174
CAN004909	MI	163	165	211	211	143	153	150	154	135	135	200	202	156	158	147	149	107	109	160	166	120	124	172	174
CAN004911	MI	163	165	211	217	143	153	164	164	135	135	200	200	144	144	143	149	103	117	160	160	114	124	172	174
CAN004912	MI	165	167	211	211	153	153	154	160	131	135	202	202	154	160	141	143	107	109	160	160	116	124	172	172
CAN004913	MI	163	165	211	211	143	153	150	164	135	137	202	202	154	158	141	143	103	107	160	160	114	114	172	174
CAN004914	MI	163	163	211	211	149	153	156	160	135	137	200	200	158	158	143	149	103	117	164	166	114	120	172	174
CAN004919	MI	163	167	211	217	147	149	146	166	137	137	200	200			145	151	109	109	160	166	112	116	168	172
CAN004920	MI	163	163			153	157	164	164	133	135			144	156	143	151	103	105			114	116		

Table A3 continued

Sample	Location	cxx225		cxx200		cxx123		cxx377		cxx250		cxx204		cxx172		cxx109		cxx253		cxx442		cxx410		cxx147	
CAN004921	MI	167	167	215	217	143	143	146	150	135	135	200	206	144	144	143	143	103	103			114	116	172	174
CAN004922	MI	163	165	211	217	143	153	160	164	131	135	200	202	144	156	143	151	109	109	160	166	114	114	174	174
CAN004923	MI	163	165	211	211	147	153	150	162	131	135	202	206	144	158	143	149	103	117	160	166	118	124	174	174
CAN004924	MI	163	165	211	217	143	157	164	164	133	135	200	202	160	160	143	151	103	117	160	160	114	124	172	174
CAN004925	MI	163	167	217	229	143	143	160	164	135	137	200	202	158	160	141	143	109	109	160	166	114	116	174	174
CAN004926	MI	163	163	211	211	143	153	164	164	131	133	200	200	156	160	143	143	107	109	160	166	116	124	172	174
CAN004927	MI	167	167	215	215	143	153	146	164	131	135	200	200	158	158	143	151	103	109	160	166	114	114	172	172
CAN004928	MI	165	167	211	211	153	153	146	164	135	135	200	206	144	158	143	151	111	117	160	160	114	122	168	172
CAN004929	MI	165	165	215	217	143	153	146	164	133	135	200	200	154	154	149	151	109	109	160	166	114	114	172	174
CAN004930	MI	163	163	211	211	143	153	160	164	131	135	200	202	156	156	143	143	107	109	160	160	116	124	172	174
CAN004931	MI	163	163	205	225	153	153	154	162	135	135	200	202	144	144	143	149	111	117	160	166	118	124	172	174
CAN004932	MI	163	165	205	211	143	153	164	164	135	135	200	200	144	158	143	149	109	109	160	160	116	122	168	172
CAN005268	MI	167	171	209	217	147	149	164	164	131	139	200	202	144	158	145	151	111	113	160	160	98	120	168	176
CAN005269	MI	167	169	209	213	147	149	154	162	137	141	200	200	144	158	149	151	107	111	160	166	98	120	172	172
CAN005270	MI	163	167	211	215	149	153	146	164	131	135	200	202	154	158	143	143	103	117	160	166	114	116	172	172
CAN004815	MN	163	167	211	217	143	153	144	164	133	133	202	202	154	156	149	151	109	109	160	166	114	122	172	172
CAN004816	MN	165	165	215	229	153	157	164	164	131	135	202	202	154	158	143	143	109	109	160	166	116	124	168	174
CAN004817	MN	167	167	211	221	145	153	156	160	133	135	200	202	144	154	143	143	109	111	160	166	124	124	172	174
CAN004818	MN	163	167	217	217	143	143	160	164	133	133	200	200	144	144	143	143	109	111	160	166	116	118	172	172
CAN004819	MN	163	165	211	215	153	157	160	164	133	135	200	200	144	158	143	143	109	117	166	166	114	118	172	172
CAN004820	MN	163	165	211	217	147	153	160	164	131	131	200	200	144	158	143	143	109	109	160	166	114	116	168	172
CAN004821	MN	165	167	205	217	147	153	146	160	135	135	200	200	156	158	141	143	109	109	160	166	114	124	172	172
CAN004822	MN	163	167	211	217	143	153	160	164	135	135	200	200	154	158	143	143	109	109	160	166	114	118	172	172
CAN004823	MN	165	169	205	211	145	147	146	164	135	135	200	202	144	154	143	149	109	109	160	166	114	118	174	174
CAN004824	MN	167	169	211	211	153	153	146	170	133	135	200	200	158	158	143	143	109	109	160	166	118	122	174	174
CAN004825	MN	163	165	217	217	153	157	156	162	135	137	200	200	158	158	141	143	109	117	166	166	114	122	168	172
CAN004826	MN	165	165	217	217	143	157	162	164	133	135	200	202	156	158	143	143	109	117	164	166	114	124	168	172
CAN004827	MN	165	165	211	213	149	153	160	160	133	135	200	206	154	160	143	149	107	109	160	166	114	120	172	176
CAN004828	MN	165	167	211	211	153	157	160	160	135	135	200	200	158	158	143	151	109	117	166	166	116	120	172	172
CAN004829	MN	165	167	211	217	143	143	146	146	131	133	200	202	158	158	143	143	111	117	164	166	116	122	170	174
CAN004830	MN	163	163	217	217	153	153	160	164	133	135	200	200	144	158	143	143	111	117	160	166	114	118	172	174
CAN004831	MN	165	167	211	217	153	157	160	164	131	135	200	200	158	158	143	151	109	109	160	166	114	114	172	172

Table A3 continued

Sample	Location	cxx225		cxx200		cxx123		cxx377		cxx250		cxx204		cxx172		cxx109		cxx253		cxx442		cxx410		cxx147	
CAN004832	MN	167	167	211	211	153	157	160	164	131	131	200	202	158	158	143	151	109	109	164	166	114	116	172	174
CAN004833	MN	167	167	211	217	143	153	160	164	131	135	200	200	158	158	143	151	109	109	164	166	114	116	172	174
CAN004834	MN	163	167	211	217	153	153	160	170	131	135	200	202	144	158	143	143	109	117	166	166	122	122	172	172
CAN004835	MN	165	167	211	217	143	153	160	160	135	137	200	206	154	158	143	143	117	117	160	166	118	118	172	174
CAN004836	MN	165	167	215	217	147	153	160	160	135	137	200	200	154	158	143	149	107	117	160	166	116	122	172	172
CAN004837	MN	163	165	211	229	153	153	160	164	135	137	200	200	158	158	143	143	109	117	160	160	114	124	172	172
CAN004838	MN	163	167	215	223	153	153	150	160	135	137	200	202	158	158	141	143	117	117	160	164	114	116	172	174
CAN004839	MN	163	167	217	217	153	153	154	160	135	137	200	202	144	158	143	143	103	111	160	166	114	118	170	172
CAN004840	MN	163	167	211	217	153	153	160	164	135	139	200	200	144	158	143	149	109	109	160	166	122	122	172	174
CAN004841	MN	163	167	217	217	153	153	164	164	135	139	200	202	158	158	141	143	109	109	160	166	114	122	172	172
CAN004842	MN	163	163	211	217	143	147	164	164	135	135	200	202	144	158	143	149	103	109	160	164	114	116	172	174
CAN004843	MN	165	167	205	217	149	153	150	162	133	135	200	200	144	160	143	143	109	111	160	166	114	124	172	172
CAN004844	MN	165	165	205	229	145	157	146	160	135	135	200	200	158	158	143	151	109	117	160	160	114	114	172	174
CAN004845	MN	167	167	211	211	153	153	160	164	135	135	202	202	158	158	143	151	109	117	160	166	120	122	172	172
CAN004846	MN	163	167	217	219	149	157	154	164	131	135	202	206	144	154	143	143	109	109	166	166	98	114	174	174
CAN004847	MN	165	167	213	217	145	153	156	170	133	135	200	206	158	158	141	143	109	111	164	166	114	114	172	172
CAN004848	MN	165	167	211	229	143	153	156	162	135	145	200	206	144	158	143	151	109	109	166	166	114	120	172	172
CAN004849	MN	167	167	211	215	143	153	156	160	135	145	200	206	144	158	143	147	109	109	160	166	114	120	172	172
CAN004850	MN	165	167	215	229	145	153	154	160	135	145	200	206	144	158	143	151	109	109	160	166	114	114	172	172
CAN004851	MN	163	167	215	229	143	153	154	160	135	145	200	206	144	158	143	147	109	109	166	166	98	114	172	172
CAN004852	MN	163	163	211	215	153	153	156	160	135	135	200	200	154	158	141	143	107	111	166	166	114	124	174	174
CAN004853	MN	163	169	217	229	153	153	156	164	131	135	200	202	144	144	143	143	103	117	160	166	114	124	172	174
CAN004854	MN	163	167	211	217	153	153	146	146	135	135	200	200	144	158	143	143	109	117	160	160	114	118	172	172
CAN004855	MN	163	167	211	217	153	157	156	164	131	135	200	208	144	154	143	149	103	109	166	166	114	122	172	172
CAN004856	MN	163	167	211	211	153	153	160	164	133	143	200	206	144	158	143	143	109	117	160	166	114	114	170	172
CAN004857	MN	163	167	205	211	153	157	154	160	133	133	200	206	144	158	143	143	109	117	164	166	122	124	172	172
CAN004858	MN	163	165	217	223	145	157	154	156	131	135	200	206	144	158	143	143	109	109	160	166	114	124	172	172
CAN004859	MN	165	167	211	217	143	153	162	164	133	135	200	202	158	158	143	149	109	117	160	166	124	124	172	174
CAN004860	MN	163	167	217	217	143	153	146	162	135	135	200	200	158	158	143	149	109	117	160	160	114	124	174	174
CAN004861	MN	163	167	211	221	145	157	160	164	133	135	200	200	144	144	143	143	109	109	160	160	114	114	174	174
CAN004862	MN	165	169	205	205	147	153	146	164	131	135	202	202	144	154	143	143	109	109	160	166	114	122	172	174
CAN004863	MN	165	167	211	215	145	153	160	162	131	135	200	200	154	158	143	143	109	117	160	164	114	114	174	174

Table A3 continued

Sample	Location	cxx225		cxx200		cxx123		cxx377		cxx250		cxx204		cxx172		cxx109		cxx253		cxx442		cxx410		cxx147	
CAN005256	MN	169	171	209	215	149	155	160	166	141	143	200	202	144	158	147	151	109	113	160	172	116	118	170	170
CAN005257	MN	163	177	211	211	147	149	156	164	129	137	200	202	158	160	145	151	107	111	166	172	112	126	172	176
CAN005258	MN	169	177	211	217	147	151	156	160	139	145	200	200	144	144	147	151	111	111	160	168	98	112	172	176
CAN005259	MN	167	169	209	213	147	149	154	162	139	139	200	200	144	144	151	155	107	111	160	166	98	120	172	172
CAN004048	NEON	163	169	207	211	147	149	162	174	133	135	202	202	154	158	145	147	103	107	164	168	98	98	168	172
CAN004051	NEON	165	177	215	221	149	153	160	162	133	139	200	200	160	160	143	147	107	107	160	168	112	116	174	176
CAN004053	NEON	179	179	209	221	149	149	154	166	135	139	202	202	144	160	147	147	105	117	160	166	98	98	176	176
CAN004054	NEON	167	167	219	227	149	149	162	166	135	145	200	200	144	160	149	149	99	111	164	172	98	112	176	176
CAN004055	NEON	165	179	207	211	147	149	154	162	135	141	200	200	144	154	151	151	105	111	162	164	98	112	176	178
CAN004056	NEON	163	165	217	217	143	143	144	146	133	141	202	206	156	158	143	147	109	111	160	164	98	116	172	172
CAN004057	NEON	163	165	211	229	143	147	144	146	133	135	200	200	158	160	143	151	109	109	160	164	114	124	172	174
CAN004058	NEON	163	167	211	217	143	143	144	156	135	135	200	202	158	158	149	149	107	117	164	166	116	118	168	172
CAN004059	NEON	165	169	215	219	143	149	162	166	131	139	200	200	144	144	145	151	103	117	166	166	98	116	172	172
CAN004073	NEON	163	165	205	217	143	153	162	164	137	139	200	202	144	158	143	143	103	109	160	164	98	120	174	178
CAN004074	NEON	163	167	217	217	143	143	160	162	131	137	200	206	144	144	143	143	109	117	160	166	96	118	170	172
CAN004075	NEON	163	165	211	211	143	143	162	162	133	135	200	200	144	158	143	143	103	109	164	164	116	118	172	172
CAN004076	NEON	163	165	211	217	143	153	162	164	135	137	200	202	144	158	143	143	109	109	164	164	98	120	172	174
CAN004077	NEON	165	165	207	209	149	149	166	166	135	139	200	202	144	160	147	151	105	117	166	168	120	122	172	172
CAN004078	NEON	163	165	211	211	143	143	154	156	135	135	200	200	158	158	143	143	103	109	164	164	116	120	172	174
CAN004080	NEON	163	165	205	217	143	153	144	164	133	139	200	202	144	144	143	147	109	109	164	166	98	114	172	172
CAN004081	NEON	163	165	217	219	147	153	154	162	133	137	200	200	144	158	149	151	109	111	164	166	98	98	172	172
CAN004082	NEON	165	167	215	219	147	153	154	162	133	137	200	202	158	158	143	151	109	111	164	166	98	98	172	172
CAN004083	NEON	163	163	211	211	145	151	154	156	135	143	202	202	144	156	149	149	109	109	160	164	98	120	172	176
CAN004084	NEON	163	165	215	217	151	153	146	164	137	137	200	206	158	158	147	149	107	109	164	164	98	114	168	172
CAN004085	NEON	163	165	217	217	143	145	156	162	131	139	200	206	144	158	143	143	103	117	160	162	96	114	168	172
CAN004086	NEON	165	169	211	221	153	153	146	154	135	139	202	206	156	158	143	147	109	109	160	160	98	114	172	174
CAN004087	NEON	165	165	217	223	143	153	162	164	135	135	200	202	158	158	143	147	109	111	160	164	98	118	172	174
CAN004088	NEON	165	171	215	219	147	157	162	162	139	139	200	202	158	160	143	147	109	109	160	164	114	124	172	172
CAN004096	NEON	177	177	209	215	147	149	154	160	137	137	200	202	158	160	143	151	103	111	160	160	114	120	174	176
CAN004166	NEON	163	167	215	221	143	147	160	164	133	135	200	200	158	158	145	147	105	109	164	166	98	122	172	172
CAN004167	NEON	163	167	215	221	143	149	144	162	135	135	200	200	156	158	145	147	109	111	164	166	98	98	172	172
CAN004183	NEON	167	179	211	215	149	153	158	176	137	145	200	200	144	154	149	151	107	115	162	164	98	112	176	176

Table A3 continued

Sample	Location	cxx225		cxx200		cxx123		cxx377		cxx250		cxx204		cxx172		cxx109		cxx253		cxx442		cxx410		cxx147	
CAN004188	NEON	163	175	207	215	147	147	162	166	131	139	200	200	144	160	143	151	105	111	160	164	110	110	170	172
CAN004189	NEON	175	179	209	215	147	147	164	166	139	141	200	202	160	160	143	147	105	117	164	164	110	110	170	172
CAN004190	NEON	163	165	207	221	147	147	160	162	131	131	200	200	144	160	151	151	111	117	160	164	98	110	170	176
CAN004199	NEON	165	179	213	217	143	147	154	154	135	135	200	200	156	158	143	147	107	109	160	164	114	116	172	176
CAN004203	NEON	167	167	205	217	149	153	146	164	131	135	200	206	144	154	143	143	109	109	164	164	114	114	176	176
CAN004207	NEON	163	169	211	217	145	149	160	164	133	135	200	200	144	158	143	143	103	109	164	166	96	98	172	178
CAN004221	NEON	165	167	217	223	143	143	136	150	131	143	200	206	156	158	141	143	109	109	160	160	114	122	172	174
CAN004222	NEON	163	165	217	217	143	153	150	160	133	143	200	200	156	156	143	147	109	109	160	164	114	122	172	172
CAN004223	NEON	163	165	217	223	143	153	136	150	131	133	200	200	158	158	147	147	109	109	160	164	114	120	172	172
CAN004224	NEON	163	165	205	215	145	145	146	154	131	135	200	202	158	158	147	147	107	109	160	164	118	120	172	178
CAN004225	NEON	163	165	217	223	143	143	150	160	131	143	200	206	156	158	141	143	109	109	160	164	114	122	172	174
CAN004226	NEON	163	167	205	217	145	157	146	160	131	131	200	202	158	158	147	147	107	111	160	160	114	118	174	178
CAN004227	NEON	165	167	217	223	143	143	156	160	133	143	200	200	156	158	143	147	109	109	160	164	114	122	172	172
CAN004228	NEON	163	165	217	217	143	153	136	156	131	143	200	200	156	158	147	147	109	109	160	160	114	122	172	174
CAN004229	NEON	165	165	205	229	147	151	144	160	133	133	200	202	158	158	147	149	109	109	160	166	98	118	168	172
CAN004230	NEON	163	165	211	211	143	153	156	162	135	141	200	200	144	158	143	143	107	109	160	166	98	118	172	174
CAN004243	NEON	163	167	213	217	143	153	144	144	133	133	200	208	158	158	143	147	109	109	164	166	114	114	172	172
CAN004466	NEON	165	171	211	223	149	153	162	164	137	139	200	200	144	158	143	143	103	109	160	160	114	114	168	178
CAN004468	NEON	169	169	215	223	143	147	144	160	137	139	200	202	156	158	147	149	103	109	160	164	114	120	172	172
CAN004469	NEON	167	177	207	215	147	147	154	156	135	137	200	202	144	160	147	151	113	117	160	168	112	112	172	176
CAN004470	NEON	165	169	209	215	143	147	156	162	135	137	200	206	156	156	143	149	109	117	164	164	114	118	170	172
CAN004471	NEON	163	165	217	221	153	153	164	174	135	137	200	200	144	158	143	143	109	109	160	160	98	114	172	172
CAN004472	NEON	165	167	211	211	143	143	158	160	137	137	200	200	144	156	143	143	109	109	160	160	96	116	172	176
CAN004473	NEON	163	165	215	217	151	153	162	164	133	135	200	200	158	158	143	149	109	117	164	166	114	120	172	172
CAN004474	NEON	163	167	215	217	143	143	136	144	135	135	200	202	144	154	143	143	109	117	160	168	114	114	172	178
CAN004475	NEON	163	165	217	217	143	143	150	154	135	135	200	200	156	158	143	149	109	109	160	164	114	120	168	172
CAN004476	NEON	167	167	221	221	147	153	154	158	131	135	206	206	144	144	143	143	103	109	164	166	98	122	170	174
CAN004477	NEON	165	167	217	229	143	143	160	162	131	135	200	208	144	158	143	143	109	111	160	164	114	114	168	174
CAN004478	NEON	163	165	217	221	153	153	158	174	135	139	200	202	154	158	143	143	107	109	160	164	114	114	172	172
CAN004479	NEON	165	169	215	217	143	153	154	162	131	137	200	208	156	158	143	147	103	117	160	164	114	114	168	168
CAN004482	NEON	165	167	211	213	147	147	154	156	135	139	200	200	156	158	143	143	109	117	160	164	114	114	172	178
CAN004484	NEON	163	163	211	219	143	143	144	164	135	141	200	206	144	156	143	143	109	117	160	166	98	98	172	178

Table A3 continued

Sample	Location	cxx225		cxx200		cxx123		cxx377		cxx250		cxx204		cxx172		cxx109		cxx253		cxx442		cxx410		cxx147	
CAN004485	NEON	163	163	211	223	143	153	154	156	135	135	200	200	144	158	143	147	103	109	164	166	116	120	172	172
CAN004486	NEON	165	169	215	223	147	153	156	160	135	141	200	200	158	158	143	145	105	109	160	166	98	114	168	168
CAN004488	NEON	165	167	205	211	147	147	154	154	137	143	200	200	156	158	143	143	103	109	160	164	96	114	168	172
CAN004489	NEON	163	165	211	211	143	153	156	162	135	135	200	208	144	144	143	143	103	109	164	164	116	120	172	174
CAN004502	NEON	163	165	221	227	147	147	156	156	135	145	202	202	144	160	143	149	103	113	162	166	112	120	168	178
CAN004503	NEON	165	179	215	221	147	149	158	166	139	141	200	200	160	160	147	151	103	117	160	166	114	122	172	172
CAN004505	NEON	165	167	219	227	147	147	158	166	139	141	200	200	144	160	147	151	105	105	160	166	98	110	176	178
CAN004523	NEON	163	167	211	221	149	153	154	160	131	139	200	200	144	158	143	143	103	107	160	164	96	114	168	174
CAN004527	NEON	167	169	211	223	143	147	154	156	135	135	200	200	156	158	143	145	103	109	160	164	98	98	168	176
CAN004530	NEON	167	169	217	217	145	147	150	160	133	139	200	202	160	160	143	151	105	111	164	166	98	122	168	176
CAN004608	NEON	163	163	211	223	143	157	146	156	135	137	200	202	158	158	143	149	103	111	160	166	116	120	168	172
CAN004609	NEON	165	165	213	215	143	149	146	160	139	143	200	202	156	158	143	149	103	109	160	160	98	98	168	174
CAN004610	NEON	165	167	211	223	145	145	154	156	135	141	206	208	156	158	147	147	109	109	160	160	98	116	172	172
CAN004613	NEON	163	167	213	217	153	153	146	162	135	135	200	206	144	158	143	149	105	109	164	166	96	118	172	174
CAN004614	NEON	165	167	215	217	143	143	162	164	135	135	200	202	158	158	143	147	109	109	164	164	98	120	172	174
CAN004615	NEON	167	167	211	221	147	157	144	154	135	137	200	200	156	158	143	143	109	111	160	166	116	118	172	172
CAN004616	NEON	163	167	211	221	147	157	154	156	135	137	200	208	156	158	143	149	109	111	160	164	96	116	172	172
CAN004617	NEON	169	179	209	221	147	149	154	156	135	137	202	202	144	160	151	155	113	117	162	172	98	118	168	178
CAN004618	NEON	165	165	205	211	153	153	144	146	135	139	200	208	158	160	143	143	109	111	160	164	114	120	172	174
CAN004619	NEON	165	167	211	223	143	143	154	156	135	135	206	208	158	158	147	147	109	111	160	160	98	118	172	172
CAN004621	NEON	163	165	205	211	143	153	146	162	135	135	200	208	158	158	143	143	109	109	160	164	98	120	172	172
CAN004622	NEON	163	165	211	211	149	153	144	146	139	139	200	200	144	160	143	147	109	111	160	164	114	114	172	174
CAN004623	NEON	167	167	211	221	147	157	144	154	135	137	200	200	158	158	141	149	109	111	160	164	96	116	172	172
CAN004641	NEON	165	167	217	217	143	143	146	160	131	135	200	202	144	158	143	145	109	109	160	166	114	116	168	168
CAN004643	NEON	163	165	217	217	149	153	154	160	135	135	200	206	144	158	143	143	103	107	160	166	114	118	172	174
CAN004647	NEON	163	163	217	217	143	143	146	160	131	135	202	202	144	144	143	145	109	109	164	164	96	116	170	174
CAN004870	NEON	163	167	217	217	147	147	146	156	135	139	200	200	158	158	143	143	107	109	160	164	120	124	170	172
CAN004871	NEON	163	165	213	217	143	143	146	164	133	135	200	206	158	158	143	143	103	103	160	164	116	118	172	172
CAN004873	NEON	169	177	207	209	149	151	154	154	137	139	200	200	154	160	145	151	107	107	162	166	112	120	172	172
CAN005263	NEON	163	167	217	223	153	153	144	164	131	143	200	202	158	158	143	147	103	103	160	160	114	118	168	172
CAN005264	NEON	163	167	211	217	151	153	156	164	133	135	202	202	156	158	147	147	109	111	160	160	98	120	174	174
CAN005265	NEON	163	163	205	211	143	147	154	154	135	135	200	208	158	158	147	147	109	109	160	164	118	124	174	174

Table A3 continued

Sample	Location	cxx225		cxx200		cxx123		cxx377		cxx250		cxx204		cxx172		cxx109		cxx253		cxx442		cxx410		cxx147	
CAN005266	NEON	163	165	205	213	143	153	162	162	133	135	200	208	144	158	147	149	109	111	160	164	114	120	172	172
CAN004032	NWON	165	165	211	215	143	153	160	162	135	141	200	202	144	154	143	145	109	109	166	166	98	124	168	172
CAN004064	NWON	165	167	211	217	153	157	156	162	133	135	200	202	144	144	143	143	109	111	160	166	98	122	174	176
CAN004065	NWON	163	167	211	215	147	153	154	160	135	137	200	202	158	160	143	143	107	111	160	164	116	122	172	174
CAN004067	NWON	165	167	211	217	145	153	150	160	131	135	202	206	158	158	149	151	109	117	160	166	114	116	172	172
CAN004068	NWON	167	169	213	215	145	153	160	160	135	139	200	202	144	144	143	149	109	117	164	166	118	118	172	174
CAN004070	NWON	165	167	215	217	143	153	146	164	133	137	200	202	158	158	143	149	111	117	160	166	114	120	172	174
CAN004071	NWON	167	167	215	215	143	153	160	160	135	143	200	200	144	158	143	143	109	117	160	164	116	118	174	174
CAN004072	NWON	167	169	211	217	143	145	150	160	131	135	202	206	154	158	143	149	109	117	160	166	116	116	172	172
CAN004091	NWON	163	169	205	211	145	147	154	154	135	139	200	208	156	158	143	147	109	109	160	160	118	124	174	174
CAN004092	NWON	167	169	213	215	143	145	160	160	135	143	200	202	144	156	143	143	111	117	160	166	118	118	172	174
CAN004093	NWON	163	167	215	217	145	157	160	164	135	135	200	200	144	158	147	151	103	109	160	160	118	118	172	174
CAN004095	NWON	163	167	211	217	143	153	144	162	135	135	200	208	144	158	143	143	109	111	160	160	114	124	172	176
CAN004097	NWON	165	167	205	229	143	143	156	160	133	135	200	200	158	158	149	149	103	111	160	160	114	114	168	176
CAN004100	NWON	163	165	215	215	143	145	160	164	131	133	200	202	154	158	143	149	111	111	166	166	120	124	172	174
CAN004101	NWON	163	169	211	215	143	151	146	154	133	135	200	200	156	158	145	147	109	111	160	160	98	114	172	176
CAN004102	NWON	163	167	211	217	147	153	164	164	135	135	200	202	144	144	143	143	109	117	164	166	114	114	172	176
CAN004103	NWON	165	167	215	217	153	157	160	170	135	135	202	202	144	158	143	143	109	111	160	166	116	118	172	176
CAN004104	NWON	163	165	215	217	153	153	160	164	135	139	200	200	158	158	147	147	109	117	160	166	116	118	172	172
CAN004105	NWON	167	169	217	217	143	145	146	160	133	135	200	202	158	160	143	147	107	109	160	164	114	124	172	172
CAN004106	NWON	163	163	211	215	143	147	154	156	133	135	200	206	158	158	143	143	111	117	164	166	114	114	174	178
CAN004107	NWON	163	163	211	211	143	149	154	154	135	143	200	206	156	158	143	143	109	117	164	164	114	114	174	174
CAN004108	NWON	167	167	205	217	145	153	154	156	131	135	200	200	158	158	143	151	103	109	160	166	118	124	172	174
CAN004109	NWON	163	165	211	229	143	149	154	156	135	139	202	206	158	158	143	143	109	109	160	160	114	120	172	176
CAN004110	NWON	163	163	211	215	145	151	156	160	133	141	200	200	158	158	143	143	109	109	160	164	98	114	172	178
CAN004112	NWON	165	167	211	211	145	153	146	158	131	135	200	200	158	158	143	143	109	109	160	160	98	114	172	174
CAN004113	NWON	163	169	211	211	147	153	160	160	131	135	200	200	156	158	141	143	109	117	160	160	114	116	172	174
CAN004114	NWON	163	165	211	211	149	151	156	164	133	133	200	200	158	158	143	143	109	109	160	160	114	120	172	176
CAN004115	NWON	163	167	215	215	151	153	160	160	133	133	200	202	158	158	143	151	109	109	160	160	114	118	172	176
CAN004116	NWON	165	167	217	217	147	147	160	160	133	135	200	202	154	158	143	143	109	117	160	160	114	114	172	174
CAN004117	NWON	165	167	211	211	149	157	160	160	131	135	206	208	154	158	143	149	109	109	160	166	98	114	172	176
CAN004118	NWON	165	165	217	223	143	153	146	160	135	135	200	202	158	158	143	143	109	109	160	166	98	114	172	172

Table A3 continued

Sample	Location	cxx225		cxx200		cxx123		cxx377		cxx250		cxx204		cxx172		cxx109		cxx253		cxx442		cxx410		cxx147	
CAN004119	NWON	163	163	211	217	153	153	144	162	135	143	200	208	144	158	143	143	109	109	160	160	114	124	172	176
CAN004120	NWON	165	167	205	211	143	153	160	170	135	135	200	202	156	158	143	143	109	111	160	164	98	114	172	174
CAN004121	NWON	165	167	211	211	145	145	160	162	135	135	200	206	156	160	143	149	109	109	160	166	124	124	172	172
CAN004123	NWON	163	169	211	215	145	153	150	164	133	135	202	206	144	144	143	143	109	109	160	166	114	114	172	172
CAN004124	NWON	163	163	205	205	143	153	164	164	131	135	202	202	144	158	143	143	109	109	160	160	114	114	172	174
CAN004125	NWON	163	163	211	217	153	153	160	160	135	143	200	202	154	156	143	143	109	109	166	166	98	114	172	174
CAN004126	NWON	163	165	205	211	145	147	154	170	135	135	202	202	158	158	143	143	103	109	166	166	114	118	168	174
CAN004128	NWON	167	169	209	211	145	149	164	164	139	139	200	200	158	160	143	147	105	115	160	168	98	98	172	180
CAN004129	NWON	165	165	227	227	147	149	160	164	133	139	200	200	144	144	149	149	105	113	172	172	98	116	172	172
CAN004130	NWON	165	171	211	227	149	149	160	164	139	141	200	200	144	144	149	149	105	111	168	172	112	116	172	176
CAN004131	NWON	165	179	221	227	147	149	162	164	139	141	200	200	144	144	147	149	105	113	168	172	98	124	172	180
CAN004132	NWON	165	179	209	227	149	149	160	162	139	141	200	200	144	158	147	149	105	113	168	172	116	124	172	180
CAN004134	NWON	171	179	209	221	147	149	160	162	137	141	200	200	144	158	147	147	105	105	162	168	116	124	180	180
CAN004135	NWON	165	165	211	223	153	157	160	164	131	135	200	206	144	158	143	143	109	111	166	166	114	124	172	174
CAN004136	NWON	167	169	211	215	147	153	160	164	139	143	200	202	144	144	143	149	109	111	164	166	118	118	172	174
CAN004137	NWON	163	167	205	211	153	157	160	160	133	133	200	200	144	156	141	143	109	109	160	166	114	124	172	174
CAN004138	NWON	165	169	217	217	153	153	160	164	135	135	200	200	144	144	143	147	107	117	160	164	114	120	172	172
CAN004139	NWON	163	165	205	217	153	153	146	170	135	135	200	200	144	156	141	143	103	111	164	166	114	114	174	176
CAN004140	NWON	163	165	215	217	145	157	156	160	135	135	200	200	144	158	143	143	109	117	160	160	114	122	172	174
CAN004141	NWON	163	165	211	217	145	153	162	164	135	135	200	206	144	158	143	143	109	109	166	166	114	124	172	174
CAN004142	NWON	163	167	211	217	153	153	144	162	135	135	200	208	144	158	143	143	111	117	160	166	116	124	172	174
CAN004145	NWON	163	167	211	211	143	153	154	164	131	135	200	202	154	158	143	143	103	109	164	166	114	114	174	178
CAN004146	NWON	163	165	217	229	145	153	150	164	135	137	200	200	144	158	141	147	109	109	160	160	98	116	172	172
CAN004147	NWON	163	167	211	217	153	153	150	160	135	135	200	200	144	158	141	143	103	109	164	166	116	124	172	172
CAN004148	NWON	163	165	211	217	143	145	158	164	135	135	200	202	158	158	143	147	103	109	160	166	98	116	172	172
CAN004149	NWON	165	167	211	229	143	153	160	164	135	135	200	206	158	158	143	147	103	109	160	166	116	116	172	172
CAN004152	NWON	167	167	211	215	143	145	150	162	133	135	202	208	158	160	143	153	109	109	160	166	114	116	172	172
CAN004153	NWON	167	167	215	229	143	145	150	164	133	135	202	208	158	160	143	153	109	109	160	166	116	124	172	172
CAN004154	NWON	167	169	211	217	143	149	160	162	135	135	200	208	158	158	147	147	109	111	160	164	98	124	172	172
CAN004155	NWON	167	167	211	215	143	147	150	164	135	137	202	202	158	158	143	153	109	109	166	166	114	116	172	172
CAN004156	NWON	163	165	211	211	147	153	146	154	135	137	200	206	158	158	143	149	109	111	164	166	114	114	172	176
CAN004157	NWON	165	167	211	217	143	145	160	160	131	133	202	206	158	158	143	149	109	109	160	160	116	116	172	172

Table A3 continued

Sample	Location	cxx225		cxx200		cxx123		cxx377		cxx250		cxx204		cxx172		cxx109		cxx253		cxx442		cxx410		cxx147	
CAN004158	NWON	167	167	229	229	149	153	144	146	135	135	200	200	144	156	141	149	109	111	160	166	114	124	174	174
CAN004159	NWON	167	167	215	229	153	153	144	162	131	135	200	200	144	158	143	149	109	109	160	166	98	118	172	174
CAN004160	NWON	169	169	205	217	143	145	162	164	133	135	200	200	144	158	143	149	109	117	160	166	114	124	172	178
CAN004161	NWON	163	165	215	217	145	145	160	164	135	135	200	200	158	158	143	151	109	111	160	164	118	118	172	172
CAN004162	NWON	165	167	215	229	145	153	154	162	135	135	202	202	144	158	149	149	109	111	160	160	114	124	174	174
CAN004163	NWON	163	163	211	229	145	153	158	162	133	137	200	202	144	158	143	147	111	117	160	166	114	118	172	172
CAN004164	NWON	163	167	211	229	145	153	146	162	131	135	200	202	158	158	149	149	109	111	160	166	114	114	174	174
CAN004165	NWON	163	165	211	211	147	157	150	164	135	135	200	200	158	158	143	143	109	109	160	166	114	116	172	174
CAN004168	NWON	167	169	211	217	143	145	160	160	131	133	202	206	154	158	143	149	109	109	160	166	116	116	172	172
CAN004169	NWON	165	167	211	229	145	145	154	160	133	135	200	200	158	158	141	143	103	109	160	160	114	116	172	172
CAN004172	NWON	163	167	211	217	143	145	146	160	135	137	200	202	156	158	143	143	111	111	164	166	114	124	172	174
CAN004173	NWON	163	165	211	215	149	153	154	156	135	135	200	202	144	158	143	143	109	109	164	166	114	124	172	174
CAN004174	NWON	163	165	211	219	149	153	146	164	135	139	202	202	156	158	143	147	109	109	166	166	98	98	168	174
CAN004175	NWON	163	165	211	213	143	149	146	146	135	139	202	202	144	158	143	143	109	109	160	166	98	124	168	174
CAN004176	NWON	165	167	215	223	153	157	162	164	135	135	200	202	154	158	141	143	109	117	164	166	114	114	168	174
CAN004185	NWON	163	167	211	217	149	153	160	164	133	133	200	202	144	144	147	147	109	109	164	164	98	98	174	178
CAN004186	NWON	163	165	217	219	143	153	154	164	135	139	202	202	156	158	143	147	109	109	164	166	98	114	172	174
CAN004467	NWON	167	167	211	215	147	153	144	144	135	143	202	202	158	160	143	143	109	109	160	164	114	114	176	176
CAN004480	NWON	165	167	215	215	149	153	160	164	133	135	200	202	158	158	141	151	109	109	160	160	116	118	176	176
CAN004481	NWON	163	165	211	215	149	151	160	164	133	133	200	202	158	158	145	151	109	117	160	164	118	118	172	176
CAN004496	NWON	165	167	211	229	153	157	150	162	135	135	202	202	144	158	143	145	109	109	160	166	114	124	168	172
CAN004611	NWON	163	165	211	213	143	153	146	150	139	141	200	202	144	158	143	149	103	109	160	166	98	124	174	176
CAN004612	NWON	163	169	211	211	147	153	162	164	135	135	200	200	144	156	143	149	117	117	164	166	120	122	168	176
CAN005260	NWON	163	163	211	229	143	153	146	170	135	143	202	202	158	158	143	143	111	117	160	166	114	116	172	176
CAN001000	NWT	163	169	215	223	151	153	164	164	131	133	202	206	156	158	145	149	109	109	160	160	120	122	172	176
CAN001001	NWT	163	163	211	215	143	149	144	154	133	139	200	202	156	156	145	147	109	109	160	164	98	116	172	174
CAN001002	NWT	163	163	219	223	143	151	144	154	133	137	200	202	156	156	147	149	109	109	166	166	114	116	172	172
CAN001003	NWT	163	167	215	215	143	153	144	154	135	137	202	206	156	158	145	147	103	109	160	166	98	120	172	174
CAN001004	NWT	165	169	217	219	143	147	144	164	133	139	202	206	156	158	145	147	109	109	160	166	116	118	172	172
CAN001005	NWT	163	167	215	217	143	145	144	160	135	139	202	206	156	156	143	147	109	113	160	160	116	122	172	172
CAN001006	NWT	163	169	211	215	143	149	144	154	135	141	206	208	158	158	143	147	109	109	160	164	98	98	172	176
CAN001007	NWT	163	169	211	215	143	149	154	154	131	141	206	206	158	158	145	147	109	109	160	160	98	116	172	176

Table A3 continued

Sample	Location	cxx225		cxx200		cxx123		cxx377		cxx250		cxx204		cxx172		cxx109		cxx253		cxx442		cxx410		cxx147	
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CAN001009	NWT	167	167	211	215	143	145	144	154	135	141	206	208	156	156	143	151	109	109	160	160	116	120	172	176
CAN001010	NWT	163	167	211	215	143	149	154	164	135	135	206	206	156	156	145	151	109	109	166	166	98	120	176	176
CAN001011	NWT	163	167	211	223	143	149	162	164	133	139	202	206	156	158	145	147	107	107	160	160	116	116	172	176
CAN001012	NWT	163	167	211	215	143	149	154	164	135	137	206	208	156	158	145	151	109	109	160	166	98	116	172	176
CAN001013	NWT	163	163	211	223	143	143	154	164	135	141	206	208	156	158	147	149	109	109	160	166	114	116	172	176
CAN001014	NWT	163	163	211	221	143	143	144	162	133	133	206	208	156	156	147	147	109	109	160	166	114	120	172	174
CAN001015	NWT	163	163	215	219	143	143	144	160	133	137	206	206	156	156	145	147	111	113	160	160	118	118	172	174
CAN001016	NWT	163	163	215	223	143	145	156	162	135	141	206	208	156	156	145	145	111	117	160	166	114	116	172	172
CAN001018	NWT	167	167	215	215	143	143	154	164	135	137	206	208	156	156	145	151	109	109	160	166	98	98	176	176
CAN001019	NWT	163	163	211	217	145	147	156	160	139	141	202	206	156	158	143	149	109	109	160	160	114	116	172	172
CAN001020	NWT	163	163	217	223	143	149	156	164	135	137	206	208	156	158	147	149	109	109	160	166	114	122	172	172
CAN001021	NWT	163	169	211	223	143	151	154	158	133	135	200	206	156	156	145	149	109	109	160	166	98	116	172	176
CAN001023	NWT	163	163	211	223	143	147	162	164	135	139	202	206	156	158	149	149	109	109	160	160	98	116	172	176
CAN001024	NWT	163	167	211	211	143	145	144	160	133	139	202	206	156	158	143	147	109	113	160	166	114	122	172	172
CAN001026	NWT	163	163	223	223	143	149	164	168	135	141	202	206	156	158	147	149	109	109	160	166	114	122	172	172
CAN001027	NWT	163	169	211	211	143	151	158	164	135	139	206	208	156	156	145	147	109	109	166	166	98	98	172	174
CAN001031	NWT	163	167	211	211	143	151	154	164	137	141	202	206	156	158	143	149	109	109	166	166	98	120	172	172
CAN001032	NWT	163	167	215	215	143	151	144	154	139	141	200	206	156	158	145	145	109	109	160	166	114	116	172	176
CAN001033	NWT	163	163	211	211	151	153	154	164	133	137	200	202	156	158	143	149	109	109	166	166	98	120	172	172
CAN001035	NWT	163	167	211	211	143	153	164	164	133	141	202	206	158	158	143	143	109	109	160	166	116	120	172	172
CAN001036	NWT	163	163	211	223	147	147	144	144	133	141	206	206	158	158	143	149	109	109	160	160	116	116	172	176
CAN001037	NWT	163	167	215	219	143	143	144	164	137	139	206	208	158	158	143	145	109	109	160	164	98	114	172	174
CAN001038	NWT	167	169	211	219	143	145	144	158	139	139	208	208	156	158	145	147	109	109	164	166	98	98	172	174
CAN001039	NWT	163	163	211	223	143	151	164	168	133	135	202	206	156	158	147	149	109	109	166	166	98	116	172	176
CAN001040	NWT	163	169	211	217	143	143	144	164	133	139	206	208	158	158	145	149	109	109			98	116	172	176
CAN001042	NWT	165	165	215	217	145	147	144	146	131	139	200	206	156	158	147	149	103	109	160	166	116	116	172	174
CAN001043	NWT	163	167	211	223	143	151	154	164	133	137	200	206	156	158	143	149	109	109	160	164	116	116	172	172
CAN001044	NWT	163	167	211	221	147	153	160	160	135	143	206	206	156	156	143	147	109	109	160	160	116	116	172	172
CAN001046	NWT	167	167	215	219	143	153	144	144	131	139	202	206	156	158	145	149	109	109	160	160	116	116	172	176
CAN001047	NWT	163	163	211	219	147	151	154	164	135	139	202	206	156	156	143	143	109	109	160	164	116	120	172	172
CAN001048	NWT	163	165	215	217	143	147	144	154	139	139	206	208	156	158	147	149	107	109	160	164	114	122	172	176

Table A3 continued

Sample	Location	cxx225		cxx200		cxx123		cxx377		cxx250		cxx204		cxx172		cxx109		cxx253		cxx442		cxx410		cxx147	
CAN001051	NWT	167	167	211	223	143	149	144	144	133	141	206	206	156	156	143	147	103	113	160	166	114	122	172	174
CAN001054	NWT	165	169	211	215	147	153	144	164	131	139	202	206	158	158	145	149	107	109	160	160	114	122	176	176
CAN001055	NWT	163	167	211	217	143	145	160	170	135	139	206	206	156	156	147	149	109	109	160	160	98	116	172	172
CAN001384	NWT	163	167	211	215	143	147	144	154	135	141	202	206	156	158	145	145	103	109	164	166	116	122	172	174
CAN001385	NWT	163	167	211	215	143	147	158	164	135	135	202	206	156	158	145	149	109	109	160	160	98	114	172	174
CAN001386	NWT	165	167	211	215	143	153	154	164	137	139	206	206	158	158	147	151	109	109	160	166	98	120	172	176
CAN001387	NWT	165	167	211	219	143	153	144	154	137	141	206	208	156	158	143	149	109	117	160	166	116	116	172	176
CAN001388	NWT	163	163	217	219	143	147	144	154	137	137	200	208	156	158	143	145	109	109	160	166	116	122	172	172
CAN001389	NWT	163	167	211	219	143	143	158	164	135	139	206	206	156	158	147	149	109	109	160	160	98	114	174	176
CAN001390	NWT	163	165	211	223	143	149	144	154	133	135	206	206	156	158	143	149	109	111	160	166	114	116	172	172
CAN001391	NWT	163	163	211	215	143	145	144	160	135	139	206	206	156	156	143	147	109	109	160	166	116	116	172	174
CAN001392	NWT	163	163	211	211	147	153	156	164	135	137	206	206	156	156	143	147	109	109	160	160	98	114	172	176
CAN001393	NWT	169	169	215	219	143	143	144	144	139	141	202	206	156	156	147	149	109	111	164	164	98	122	172	172
CAN001394	NWT	163	167	211	215	147	153	144	160	137	139	206	208	156	158	145	147	109	109	164	164	98	122	172	172
CAN001395	NWT	163	163	223	223	143	143	154	154	137	141	200	200	156	158	143	143	109	109	160	160	98	116	172	176
CAN001396	NWT	163	163	211	219	143	143	154	154	139	141	206	206	156	156	145	149	109	109	160	160	98	122	172	172
CAN000351	QUE	167	169	213	213	149	149	146	174	135	141	200	200	158	158	143	149	109	117	160	164	112	118	170	172
CAN000353	QUE	163	165	211	217	143	147	156	162	133	135	200	206	160	160	143	143	109	117	162	166	98	122	168	168
CAN000356	QUE	165	167	217	217	149	149	160	164	135	137	200	200	158	158	143	151	105	117	160	166	110	118		
CAN000357	QUE	163	163	205	215	143	143	162	162	135	135	200	208	144	158	143	145	111	117	166	166	114	118	168	172
CAN000358	QUE	163	167	215	215	149	149	146	158	135	139	200	200	144	158	143	147	107	117	160	168	118	118	168	178
CAN000359	QUE	163	163	211	215	143	143	146	162	133	135	200	200	158	158	143	145	105	109	160	166	98	114	168	172
CAN000360	QUE	167	167	207	215	147	149	158	166	135	139	200	200	156	158	143	147	111	117	160	168	118	118	172	178
CAN000362	QUE	163	163	211	215	143	143	164	164	135	135	202	208	156	158	143	147	105	109	160	164	118	118	174	178
CAN000364	QUE	163	163	211	217	143	147	136	146	131	135	200	202	144	158	143	143	109	109	166	166	98	114	168	168
CAN000370	QUE	163	163	217	221	143	153	146	164	133	135	200	200	144	144	143	145	109	109	160	166	112	114	168	172
CAN000371	QUE	163	163	211	215	143	147	136	162	131	141	200	200	156	158	143	143	109	117	164	166	114	118	168	168
CAN000372	QUE	163	169	207	217	143	143	136	158	135	139	200	202	144	158	143	151	103	109	162	164	114	118	168	172
CAN000373	QUE	163	163	211	215	143	151	162	164	135	135	200	200	144	144	143	143	103	109	160	164	98	114	168	172
CAN000374	QUE	167	179	211	211	149	149	166	172	135	139	202	202	154	158	147	147	113	117	164	166	98	118	174	176
CAN000384	QUE	167	167	205	211	143	151	164	164	131	135	200	202	156	158	143	149	105	109	160	164	118	118	174	178
CAN000386	QUE	163	165	211	215	143	143	154	160	135	135	200	200	154	160	143	143	105	109			98	110		

Table A3 continued

Sample	Location	cxx225		cxx200		cxx123		cxx377		cxx250		cxx204		cxx172		cxx109		cxx253		cxx442		cxx410		cxx147	
CAN001595	QUE	163	167	217	217	143	151	156	156	135	137	200	200	144	156	143	147	109	109	160	160	96	96	172	176
CAN001598	QUE	163	163	211	211	143	147	146	154	135	135	202	202	144	156	143	143	105	109	160	166	114	114	172	174
CAN001599	QUE	167	171	217	221	145	147	156	164	135	139	200	206	154	158	143	143	105	109			114	116		
CAN001601	QUE	165	167	215	215	143	153	156	160	131	137	200	200	154	156	143	143	105	109	160	160	114	124	168	172
CAN001602	QUE	165	165	211	211	143	147	146	162	139	141	200	202	144	158	141	147	109	109	160	164	96	114	172	174
CAN001603	QUE	165	165	213	217	143	153	156	162	135	135	200	200	144	158	143	147	103	109	160	166	114	116	172	174
CAN001614	QUE	163	163	213	213	143	151	154	164	131	135	202	206	144	158	143	143	109	111	160	166	114	118	168	168
CAN001616	QUE	167	169	211	217	143	149	154	164	131	133	200	200	144	154	143	143	109	117	164	166	114	118	168	178
CAN001617	QUE	163	167	213	215	143	147	154	154	137	139	200	200	144	158	143	149	105	109	160	164	114	116	172	174
CAN001618	QUE	167	171	205	207	149	151	156	164	135	135	200	202	144	158	143	151	109	111	166	166	96	114		
CAN001619	QUE	165	167	205	213	147	149	154	164	135	137	200	200	156	160	143	145	117	117	164	164	114	114	168	168
CAN001620	QUE	165	167	215	215	143	147	154	156	135	137	200	200	144	144	143	149	103	105	164	164	114	114	168	174
CAN001621	QUE	163	167	215	217	143	143	154	164	135	137	200	206	144	154	143	143	109	109	160	164	98	118	168	168
CAN001622	QUE	163	167	211	215	143	143	154	156	135	141	200	200	158	158	143	143	103	117	160	164	114	114	168	176
CAN001623	QUE	163	167	213	223	143	143	154	154	135	137	200	200	144	158	147	149	107	109	160	166	114	124		
CAN002268	QUE	163	167	215	217	153	153	162	164	135	141	200	200	144	144	143	149	109	117	164	166	98	118	172	178
CAN002318	QUE	167	169	211	217	143	153	144	156	135	137	200	200	144	144	143	151	103	109	162	166	114	116	172	174
FICQB99-13	QUE	167	167	211	217	149	153	150	164	131	131	200	202	158	158	143	147	105	109	160	160	98	116	172	174
CAN000120	TX	165	167	209	209	147	149	156	168	133	139	200	202	144	158	147	149	101	107	164	172	116	118	176	178
CAN000121	TX	165	165	217	221	149	153	168	170	133	135	200	200	144	144	149	151	107	109	164	168	118	124	174	176
CAN000122	TX	163	167	209	219	147	153	158	164	133	139	200	200	144	144	143	147	107	107	164	172	96	122	178	180
CAN000123	TX	163	167	217	221	147	157	150	158	137	141	200	200	144	160	145	147	109	111	166	166	108	116	168	176
CAN000124	TX	163	165	211	215	149	151	150	166	129	133	200	200	144	160	147	147	109	119	164	164	120	122	170	176
CAN000125	TX	165	167	209	209	147	151	150	166	139	139	200	200	144	144	147	149	103	109	164	166	118	118	172	174
CAN000126	TX	163	165	209	209	147	151	150	168	139	141	200	202	144	158	145	147	103	105	164	166	116	124	174	176
CAN000128	TX	163	165	209	219	147	151	154	158	137	139	200	200	144	144	147	149	109	109	164	166	112	118	166	178
CAN000129	TX	163	169	209	209	147	149	168	168	133	133	200	200	144	156	145	145	107	115	164	164	112	116	172	176
CAN000130	TX	163	167	211	219	153	157	156	166	133	145	200	202	160	160	147	147	101	107	164	164	118	124	168	174
CAN000131	TX	165	165	213	213	147	149	154	164	137	139	200	200	144	158	143	149	103	109	164	172	108	116	172	180
CAN000132	TX	163	169	209	219	147	151	156	160	133	145	200	202	144	144	145	147	109	109	162	164	108	118	176	176
CAN000133	TX	165	165	209	213	147	153	162	164	133	143	200	200	144	156	145	149	107	111	164	168	116	116	168	170
CAN000134	TX	165	165	213	217	145	149	150	164	137	139	200	200	158	160	145	147	103	107	164	168	116	120	176	182

Table A3 continued

Sample	Location	cxx225		cxx200		cxx123		cxx377		cxx250		cxx204		cxx172		cxx109		cxx253		cxx442		cxx410		cxx147	
CAN000135	TX	167	169	211	215	145	149	156	166	135	139	200	202	144	156	147	149	103	109	164	164	108	108	170	182
CAN000137	TX	167	167	217	217	143	143	150	166	139	141	200	202	144	144	149	149	101	103	164	168	116	124	170	170
CAN000138	TX	165	167	209	223	147	153	154	154	133	139	200	202	144	144	145	147	109	115	160	166	108	110	174	176
CAN000139	TX	165	165	209	209	147	149	154	154	135	135	200	202	144	144	147	149	103	109	160	164	108	118	176	184
CAN000140	TX	165	165	209	211	147	149	150	150	143	145	200	202	144	144	147	147	105	107	164	164	116	118	172	178
CAN000141	TX	165	165	207	209	143	149	150	156	133	139	202	202	144	160	145	145	109	109	162	168	116	124	172	174
CAN000142	TX	163	167	213	215	145	151	164	166	139	139	200	200	144	156	147	147	103	103	164	164	108	116	170	174
CAN000143	TX	163	165	221	221	147	147	156	170	133	139	200	200	144	160	149	149	103	109	162	164	118	120	172	174
CAN000144	TX	165	165	219	221	147	149	160	160	139	145	200	202	144	158	143	147	109	115	166	168	116	118	174	180
CAN000145	TX	163	165	209	219	147	149	150	170	133	139	200	202	144	144	145	147	107	109	160	164	112	116	174	180
CAN004864	WI	163	163	217	217	143	153	146	146	131	135	200	206	144	144	143	143	109	117	160	164	114	114	172	172
CAN004865	WI	165	165	221	221	145	149	144	160	139	145	200	200	144	144	151	155	109	115	168	168	108	114	172	180
CAN004866	WI	167	169	217	221	147	153	164	166	133	139	200	202	144	160	143	155	105	107	172	172	108	116	168	176
CAN004933	WI	163	167	207	217	153	153	160	160	131	131	206	206	144	158	143	143	109	109	166	166	114	124	174	174
CAN004934	WI	163	165	211	217	149	153	150	154	133	135	200	202	144	158	143	149	109	109	160	166	114	114	174	174
CAN004935	WI	165	165	211	217	153	153	150	160	135	135	200	202	158	158	143	143	109	109	164	166	116	120	172	174
CAN004936	WI	163	165	211	217	153	153	136	162	131	135	200	200	144	158	143	143	103	117	160	166	114	120	172	174
CAN004937	WI	163	163	211	217	153	157	162	164	131	139	200	200	158	158			109	109			114	116		
CAN004938	WI	163	163	211	217	147	153	164	170	131	135	200	202	144	158	143	151	103	109	160	164	118	118	172	174
CAN004939	WI	163	167	211	217	147	153	162	164	135	139	200	202	144	156	143	143	107	109	160	164	114	124	172	174
CAN004940	WI	163	163	211	211	143	149	164	164	135	135	200	200	156	158	143	143	109	109	166	166	114	116	172	172
CAN004941	WI	163	167	211	211	143	153	150	154	131	135	200	202	154	158	143	143	103	111	160	164	114	114	174	174
CAN004942	WI	163	167	211	217	153	153	156	160	131	135	200	200	154	158	141	151	109	109	160	164	114	118	174	174
CAN004943	WI	163	165	211	211	143	153	136	154	131	133	200	202	154	156	143	149	109	109	160	164	114	114	172	174
CAN004944	WI	163	165	211	211	143	143	160	164	135	135	206	206	156	158	149	151	109	111	160	160	114	122	174	174
CAN004945	WI	163	165	211	211	147	153	164	164	135	135	200	200	158	158	143	151	111	117	160	160	114	122	168	172
CAN004946	WI	163	165	211	215	147	153	150	164	131	135	200	202	144	158	143	143	107	109	160	166	114	122	172	172
CAN004947	WI	163	165	211	229	143	153	150	160	131	135	202	202	144	158	141	143	109	117	166	166	116	120	174	174
CAN004948	WI	163	165	211	211	143	147	160	164	131	135	200	202	144	158	143	149	109	109	160	160	114	124	172	174
CAN004949	WI	163	169	211	217	143	145	150	162	131	135	202	202	144	156	143	149	107	111	160	160	114	116	172	172
CAN004950	WI	165	169	211	217	143	157	160	164	135	135	200	202	154	160	143	149	109	117	160	166	98	124	172	174
CAN004951	WI	167	167	211	211	147	157	160	164	133	135	200	202	156	158	143	149	117	117	164	166	114	114	174	174

Table A3 continued

Sample	Location	cxx225		cxx200		cxx123		cxx377		cxx250		cxx204		cxx172		cxx109		cxx253		cxx442		cxx410		cxx147	
CAN004952	WI	163	165	211	217	153	153	164	164	133	133	206	206	158	158	143	151	109	109	160	166	124	124	174	174
CAN004953	WI	165	167	205	211	153	157	164	164	133	135	200	206	144	154	143	143	117	117	160	160	114	116	172	172
CAN004954	WI	163	169	217	217	153	153	160	164	133	135	200	200	144	144	143	143	109	111	160	166	118	124	172	174
CAN004955	WI	163	165	211	217	147	153	162	164	139	139	200	202	158	160	143	149	109	117	166	166	114	114	170	174
CAN004956	WI	167	169	211	215	153	153	164	164	131	133	200	202	144	158	141	143	109	117	160	160	116	116	170	174
CAN004957	WI	165	165	211	215	143	153	154	164	131	133	200	202	144	158	141	143	109	117	160	164	116	116	170	172
CAN004958	WI	163	163	211	217	153	153	164	164	131	135	200	200	144	158	143	151	103	103	160	164	114	114	174	174
CAN004959	WI	165	167	211	215	143	153	154	160	133	133	200	206	144	158	141	143	107	117	164	166	114	116	172	172
CAN004960	WI	165	167	211	211	143	153	160	164	133	141	202	202	154	158	141	143	103	111	160	160	114	116	172	174
CAN004961	WI	165	167	217	229	143	149	144	160	133	135	202	202	144	156	143	143	109	109	164	166	114	116	172	178
CAN004962	WI	167	167	211	211	147	157	136	164	135	137	200	202	144	158	143	143	117	117	164	166	114	122	170	174
CAN004963	WI	163	165	211	211			160	164	133	135	200	202	144	160	149	151	103	111	160	166	98	114	172	174
CAN004964	WI	165	167	215	217	143	153	150	154	131	135	200	200	154	158	143	151	103	107	160	164	114	114	170	172
CAN004965	WI	163	163	211	211	153	153	160	164	135	137	200	200	144	154	143	143	103	103	160	160	116	124	170	172
CAN004966	WI	165	167	217	217	153	153	150	150	133	135	200	200	144	158	143	151	111	117	164	166	98	114	170	172
CAN004967	WI	167	167	205	211	147	147	164	164	131	131	200	206	144	156	141	151	109	109	160	160	114	118	172	174
CAN004968	WI	165	167	211	217	153	157	150	160	133	135	200	200	144	158	143	151	103	111	164	166	98	114	172	174
CAN004969	WI	165	171	221	221	147	149	166	168	129	139	200	200	144	156	147	147	109	115	164	172	114	116	172	172
CAN004970	WI	163	165	205	217	143	147	144	164	135	139	200	200	144	156	143	143	109	109	160	160	114	114	174	174
CAN004971	WI	163	167	205	211	147	153	150	164	131	139	200	202	144	156	143	143	109	117	160	166	114	114	172	174
CAN004972	WI	165	169	209	213	145	145	160	166	133	137	202	202	144	158	143	147	107	109	164	164	98	120	170	176
CAN004973	WI	163	167	211	211	153	157	160	164	131	135	200	202	158	158	149	151	103	109	160	164	98	114	172	174
CAN004974	WI	163	167	211	217	143	153	150	164	131	135	200	202	158	158	143	151	103	111	160	164	98	98	170	174
CAN004975	WI	167	167	211	221	149	149	150	154	139	139	200	200	158	160	147	147	105	117	168	172	98	112	174	176
CAN004976	WI	163	167	211	215	147	153	146	146	135	141	206	212	158	158	149	149	109	111	160	166	116	124	172	172
CAN005261	WI	165	167	217	217	149	153	160	164	133	135	202	202	154	158	141	143	107	109	166	166	98	116	174	174

Table A4: Genetic admixture proportions of western Great Lakes region canid samples. Refer to Chapter 2 for a description of the populations inferred by STRUCTURE (P_In = I-model; P_Fn = F-model). Locations: NEON = northeastern Ontario; NWON = northwestern Ontario; MI = Michigan; WI = Wisconsin; MN = Minnesota.

Sample	Location	P_I1	P_I2	P_I3	P_I4	P_I5	P_F1	P_F2	P_F3	P_F4	P_F5	P_F6	P_F7
CAN04048	NEON	0.023	0.798	0.018	0.104	0.057	0.024	0.797	0.014	0.058	0.044	0.026	0.038
CAN04051	NEON	0.46	0.337	0.025	0.168	0.011	0.408	0.415	0.013	0.117	0.017	0.022	0.008
CAN04053	NEON	0.006	0.962	0.007	0.016	0.009	0.007	0.955	0.007	0.013	0.006	0.003	0.008
CAN04054	NEON	0.085	0.874	0.01	0.022	0.009	0.122	0.834	0.008	0.016	0.007	0.006	0.007
CAN04055	NEON	0.006	0.935	0.029	0.024	0.005	0.006	0.928	0.03	0.018	0.01	0.003	0.004
CAN04056	NEON	0.004	0.004	0.004	0.168	0.821	0.004	0.004	0.004	0.096	0.319	0.014	0.559
CAN04057	NEON	0.005	0.008	0.009	0.961	0.017	0.007	0.011	0.015	0.808	0.11	0.021	0.029
CAN04058	NEON	0.005	0.006	0.02	0.918	0.051	0.009	0.007	0.02	0.28	0.616	0.017	0.05
CAN04059	NEON	0.05	0.684	0.035	0.15	0.082	0.066	0.688	0.018	0.087	0.054	0.012	0.074
CAN04073	NEON	0.015	0.013	0.019	0.929	0.024	0.007	0.007	0.007	0.062	0.897	0.012	0.009
CAN04074	NEON	0.005	0.005	0.023	0.951	0.016	0.006	0.006	0.02	0.247	0.696	0.013	0.012
CAN04075	NEON	0.005	0.004	0.006	0.974	0.011	0.006	0.005	0.005	0.14	0.811	0.024	0.01
CAN04076	NEON	0.004	0.005	0.005	0.969	0.017	0.004	0.005	0.005	0.166	0.784	0.025	0.012
CAN04077	NEON	0.018	0.94	0.006	0.031	0.006	0.018	0.935	0.006	0.023	0.009	0.004	0.005
CAN04078	NEON	0.004	0.004	0.012	0.952	0.027	0.005	0.005	0.011	0.258	0.69	0.01	0.022
CAN04080	NEON	0.022	0.009	0.009	0.848	0.111	0.011	0.007	0.007	0.107	0.814	0.01	0.044
CAN04081	NEON	0.03	0.111	0.017	0.598	0.243	0.056	0.167	0.013	0.203	0.231	0.187	0.144
CAN04082	NEON	0.009	0.102	0.035	0.422	0.431	0.017	0.191	0.035	0.215	0.129	0.138	0.274
CAN04083	NEON	0.021	0.008	0.007	0.144	0.819	0.031	0.009	0.007	0.093	0.116	0.012	0.732
CAN04084	NEON	0.021	0.01	0.029	0.525	0.416	0.01	0.006	0.009	0.042	0.745	0.136	0.053
CAN04085	NEON	0.015	0.029	0.286	0.648	0.022	0.011	0.024	0.051	0.057	0.835	0.012	0.011
CAN04086	NEON	0.005	0.007	0.013	0.359	0.616	0.008	0.01	0.016	0.262	0.11	0.16	0.432
CAN04087	NEON	0.006	0.006	0.005	0.931	0.053	0.005	0.006	0.004	0.185	0.678	0.095	0.026
CAN04088	NEON	0.323	0.141	0.024	0.453	0.059	0.406	0.135	0.018	0.276	0.064	0.069	0.032
CAN04096	NEON	0.006	0.793	0.023	0.158	0.019	0.007	0.801	0.018	0.122	0.024	0.013	0.015
CAN04166	NEON	0.041	0.054	0.156	0.23	0.519	0.07	0.079	0.174	0.125	0.12	0.021	0.411

Table A4 continued

Sample	Location	P_I1	P_I2	P_I3	P_I4	P_I5	P_F1	P_F2	P_F3	P_F4	P_F5	P_F6	P_F7
CAN04167	NEON	0.008	0.043	0.069	0.087	0.793	0.013	0.081	0.085	0.046	0.181	0.031	0.563
CAN04183	NEON	0.016	0.916	0.018	0.042	0.008	0.013	0.905	0.016	0.031	0.008	0.021	0.006
CAN04188	NEON	0.008	0.931	0.012	0.041	0.007	0.009	0.925	0.01	0.032	0.015	0.003	0.006
CAN04189	NEON	0.048	0.901	0.016	0.028	0.007	0.039	0.904	0.015	0.023	0.009	0.004	0.006
CAN04190	NEON	0.016	0.87	0.013	0.093	0.007	0.018	0.862	0.01	0.08	0.019	0.005	0.006
CAN04199	NEON	0.041	0.046	0.372	0.271	0.27	0.055	0.07	0.284	0.081	0.269	0.134	0.106
CAN04203	NEON	0.005	0.008	0.57	0.403	0.014	0.006	0.01	0.532	0.305	0.129	0.005	0.012
CAN04207	NEON	0.016	0.013	0.068	0.884	0.019	0.015	0.011	0.035	0.148	0.707	0.071	0.013
CAN04221	NEON	0.003	0.003	0.005	0.888	0.102	0.003	0.004	0.004	0.75	0.116	0.015	0.108
CAN04222	NEON	0.009	0.004	0.004	0.891	0.092	0.016	0.005	0.004	0.599	0.216	0.046	0.112
CAN04223	NEON	0.016	0.004	0.004	0.845	0.13	0.013	0.004	0.004	0.192	0.716	0.025	0.046
CAN04224	NEON	0.051	0.009	0.02	0.755	0.165	0.023	0.006	0.011	0.071	0.812	0.044	0.033
CAN04225	NEON	0.003	0.003	0.004	0.897	0.093	0.004	0.004	0.004	0.774	0.073	0.014	0.128
CAN04226	NEON	0.017	0.008	0.006	0.948	0.021	0.036	0.01	0.006	0.532	0.39	0.012	0.014
CAN04227	NEON	0.008	0.005	0.009	0.676	0.302	0.01	0.007	0.009	0.286	0.406	0.058	0.225
CAN04228	NEON	0.01	0.005	0.005	0.855	0.125	0.009	0.006	0.004	0.293	0.593	0.012	0.082
CAN04229	NEON	0.042	0.009	0.014	0.707	0.228	0.033	0.008	0.01	0.239	0.567	0.039	0.103
CAN04230	NEON	0.006	0.008	0.01	0.956	0.021	0.008	0.009	0.009	0.381	0.551	0.025	0.018
CAN04243	NEON	0.005	0.004	0.028	0.534	0.429	0.004	0.004	0.018	0.072	0.75	0.025	0.128
CAN04466	NEON	0.024	0.049	0.457	0.441	0.028	0.028	0.055	0.209	0.084	0.491	0.117	0.015
CAN04468	NEON	0.011	0.011	0.01	0.081	0.886	0.021	0.018	0.014	0.058	0.053	0.101	0.735
CAN04469	NEON	0.004	0.954	0.015	0.019	0.008	0.005	0.949	0.014	0.015	0.006	0.003	0.007
CAN04470	NEON	0.131	0.038	0.234	0.306	0.291	0.2	0.051	0.147	0.1	0.255	0.101	0.146
CAN04471	NEON	0.007	0.044	0.055	0.864	0.03	0.005	0.068	0.022	0.259	0.151	0.484	0.011
CAN04472	NEON	0.012	0.008	0.022	0.53	0.428	0.016	0.007	0.017	0.099	0.291	0.418	0.153
CAN04473	NEON	0.007	0.005	0.013	0.946	0.03	0.006	0.006	0.011	0.244	0.695	0.019	0.019
CAN04474	NEON	0.007	0.013	0.415	0.534	0.031	0.005	0.014	0.286	0.137	0.538	0.005	0.014
CAN04475	NEON	0.004	0.004	0.016	0.938	0.038	0.007	0.005	0.012	0.259	0.663	0.026	0.028
CAN04476	NEON	0.023	0.036	0.6	0.278	0.063	0.053	0.078	0.462	0.252	0.042	0.026	0.087
CAN04477	NEON	0.003	0.005	0.011	0.971	0.011	0.003	0.005	0.008	0.343	0.614	0.018	0.009

Table A4 continued

Sample	Location	P_I1	P_I2	P_I3	P_I4	P_I5	P_F1	P_F2	P_F3	P_F4	P_F5	P_F6	P_F7
CAN04478	NEON	0.023	0.08	0.123	0.751	0.023	0.017	0.151	0.079	0.411	0.078	0.251	0.013
CAN04479	NEON	0.006	0.016	0.357	0.452	0.169	0.004	0.012	0.087	0.041	0.706	0.125	0.026
CAN04482	NEON	0.006	0.008	0.812	0.139	0.035	0.008	0.01	0.735	0.082	0.118	0.015	0.032
CAN04484	NEON	0.006	0.011	0.063	0.273	0.646	0.006	0.012	0.06	0.071	0.315	0.007	0.53
CAN04485	NEON	0.008	0.006	0.014	0.806	0.167	0.007	0.006	0.011	0.139	0.722	0.016	0.099
CAN04486	NEON	0.005	0.011	0.792	0.128	0.064	0.008	0.017	0.637	0.069	0.157	0.04	0.073
CAN04488	NEON	0.006	0.007	0.727	0.212	0.048	0.007	0.01	0.45	0.082	0.393	0.033	0.025
CAN04489	NEON	0.007	0.004	0.006	0.965	0.018	0.006	0.004	0.005	0.148	0.816	0.008	0.013
CAN04502	NEON	0.258	0.549	0.109	0.075	0.01	0.256	0.593	0.053	0.041	0.043	0.005	0.008
CAN04503	NEON	0.006	0.946	0.013	0.027	0.008	0.008	0.939	0.012	0.02	0.008	0.006	0.007
CAN04505	NEON	0.06	0.904	0.011	0.017	0.008	0.067	0.893	0.01	0.013	0.007	0.003	0.007
CAN04523	NEON	0.021	0.033	0.446	0.49	0.01	0.035	0.039	0.305	0.241	0.354	0.018	0.008
CAN04527	NEON	0.005	0.02	0.393	0.09	0.492	0.007	0.027	0.322	0.038	0.176	0.068	0.362
CAN04530	NEON	0.033	0.633	0.027	0.295	0.012	0.068	0.6	0.025	0.247	0.026	0.024	0.01
CAN04608	NEON	0.003	0.006	0.009	0.9	0.082	0.005	0.007	0.007	0.433	0.467	0.016	0.066
CAN04609	NEON	0.038	0.037	0.127	0.649	0.149	0.037	0.021	0.032	0.111	0.719	0.021	0.058
CAN04610	NEON	0.003	0.003	0.004	0.028	0.961	0.004	0.004	0.005	0.024	0.011	0.014	0.938
CAN04613	NEON	0.012	0.008	0.142	0.826	0.012	0.007	0.007	0.049	0.133	0.787	0.007	0.01
CAN04614	NEON	0.006	0.006	0.008	0.9	0.08	0.004	0.005	0.007	0.086	0.861	0.013	0.024
CAN04615	NEON	0.006	0.015	0.122	0.556	0.301	0.009	0.02	0.187	0.473	0.046	0.044	0.221
CAN04616	NEON	0.01	0.01	0.045	0.248	0.687	0.025	0.014	0.079	0.223	0.24	0.078	0.342
CAN04617	NEON	0.008	0.954	0.016	0.016	0.005	0.009	0.948	0.016	0.012	0.007	0.003	0.004
CAN04618	NEON	0.007	0.01	0.015	0.924	0.044	0.008	0.015	0.018	0.304	0.598	0.017	0.04
CAN04619	NEON	0.003	0.004	0.006	0.067	0.919	0.005	0.007	0.007	0.054	0.077	0.026	0.824
CAN04621	NEON	0.002	0.004	0.006	0.94	0.048	0.002	0.004	0.004	0.076	0.879	0.017	0.017
CAN04622	NEON	0.082	0.106	0.029	0.72	0.062	0.068	0.094	0.027	0.254	0.501	0.009	0.047
CAN04623	NEON	0.014	0.015	0.099	0.574	0.298	0.02	0.017	0.193	0.463	0.145	0.052	0.111
CAN04641	NEON	0.007	0.008	0.069	0.889	0.027	0.006	0.006	0.024	0.211	0.729	0.005	0.019
CAN04643	NEON	0.004	0.007	0.029	0.948	0.011	0.007	0.01	0.037	0.807	0.108	0.021	0.011
CAN04647	NEON	0.04	0.004	0.017	0.896	0.043	0.026	0.004	0.007	0.185	0.758	0.003	0.017

Table A4 continued

Sample	Location	P_I1	P_I2	P_I3	P_I4	P_I5	P_F1	P_F2	P_F3	P_F4	P_F5	P_F6	P_F7
CAN04870	NEON	0.03	0.017	0.033	0.906	0.014	0.058	0.02	0.03	0.516	0.349	0.016	0.012
CAN04871	NEON	0.005	0.003	0.011	0.959	0.021	0.005	0.004	0.007	0.127	0.819	0.02	0.019
CAN04873	NEON	0.024	0.917	0.02	0.02	0.019	0.033	0.896	0.017	0.015	0.01	0.011	0.019
CAN05263	NEON	0.005	0.006	0.016	0.917	0.056	0.005	0.006	0.012	0.243	0.668	0.028	0.037
CAN05264	NEON	0.006	0.004	0.004	0.419	0.566	0.007	0.005	0.004	0.275	0.167	0.008	0.534
CAN05265	NEON	0.008	0.005	0.012	0.594	0.381	0.009	0.005	0.012	0.242	0.483	0.029	0.219
CAN05266	NEON	0.016	0.007	0.009	0.901	0.068	0.006	0.005	0.005	0.049	0.899	0.021	0.016
CAN04032	NWON	0.013	0.016	0.128	0.788	0.055	0.016	0.021	0.149	0.479	0.252	0.035	0.049
CAN04064	NWON	0.007	0.018	0.011	0.948	0.016	0.011	0.035	0.015	0.847	0.06	0.013	0.02
CAN04065	NWON	0.007	0.03	0.034	0.893	0.037	0.011	0.044	0.056	0.791	0.029	0.033	0.035
CAN04067	NWON	0.003	0.004	0.005	0.971	0.017	0.003	0.005	0.005	0.953	0.01	0.009	0.016
CAN04068	NWON	0.053	0.016	0.067	0.852	0.012	0.139	0.021	0.116	0.509	0.19	0.013	0.011
CAN04070	NWON	0.003	0.005	0.008	0.97	0.015	0.004	0.007	0.009	0.812	0.134	0.02	0.016
CAN04071	NWON	0.004	0.005	0.029	0.953	0.009	0.006	0.006	0.033	0.875	0.068	0.004	0.009
CAN04072	NWON	0.003	0.003	0.007	0.945	0.041	0.004	0.004	0.007	0.91	0.011	0.019	0.045
CAN04091	NWON	0.008	0.006	0.015	0.461	0.51	0.011	0.007	0.018	0.337	0.134	0.073	0.419
CAN04092	NWON	0.007	0.007	0.032	0.936	0.017	0.018	0.013	0.063	0.652	0.22	0.017	0.017
CAN04093	NWON	0.007	0.008	0.007	0.963	0.015	0.019	0.014	0.008	0.813	0.104	0.017	0.025
CAN04095	NWON	0.003	0.006	0.011	0.881	0.099	0.004	0.007	0.012	0.379	0.368	0.125	0.105
CAN04097	NWON	0.006	0.01	0.034	0.93	0.021	0.008	0.015	0.044	0.527	0.327	0.062	0.018
CAN04100	NWON	0.003	0.005	0.007	0.97	0.014	0.004	0.006	0.007	0.939	0.021	0.008	0.015
CAN04101	NWON	0.004	0.008	0.013	0.097	0.879	0.005	0.011	0.013	0.098	0.153	0.023	0.697
CAN04102	NWON	0.005	0.01	0.049	0.925	0.01	0.008	0.015	0.075	0.816	0.067	0.007	0.011
CAN04103	NWON	0.006	0.007	0.012	0.958	0.016	0.009	0.011	0.015	0.924	0.018	0.006	0.017
CAN04104	NWON	0.026	0.012	0.01	0.864	0.088	0.044	0.013	0.011	0.434	0.388	0.019	0.091
CAN04105	NWON	0.01	0.008	0.006	0.955	0.021	0.009	0.007	0.007	0.265	0.114	0.585	0.013
CAN04106	NWON	0.004	0.007	0.169	0.778	0.042	0.004	0.008	0.179	0.303	0.466	0.005	0.034
CAN04107	NWON	0.004	0.006	0.096	0.787	0.107	0.005	0.007	0.103	0.432	0.339	0.009	0.105
CAN04108	NWON	0.003	0.006	0.026	0.957	0.009	0.004	0.008	0.031	0.899	0.034	0.015	0.008
CAN04109	NWON	0.005	0.011	0.028	0.408	0.548	0.006	0.013	0.023	0.286	0.186	0.032	0.454

Table A4 continued

Sample	Location	P_I1	P_I2	P_I3	P_I4	P_I5	P_F1	P_F2	P_F3	P_F4	P_F5	P_F6	P_F7
CAN04110	NWON	0.013	0.007	0.051	0.604	0.325	0.009	0.006	0.02	0.088	0.778	0.017	0.084
CAN04112	NWON	0.003	0.005	0.007	0.965	0.02	0.005	0.01	0.008	0.653	0.132	0.16	0.032
CAN04113	NWON	0.003	0.004	0.006	0.971	0.016	0.003	0.005	0.006	0.948	0.012	0.01	0.016
CAN04114	NWON	0.015	0.011	0.019	0.763	0.191	0.018	0.012	0.014	0.278	0.493	0.036	0.148
CAN04115	NWON	0.007	0.011	0.019	0.797	0.166	0.014	0.014	0.017	0.608	0.106	0.019	0.221
CAN04116	NWON	0.003	0.006	0.025	0.96	0.006	0.003	0.006	0.022	0.943	0.014	0.005	0.006
CAN04117	NWON	0.004	0.01	0.029	0.798	0.159	0.005	0.011	0.025	0.634	0.021	0.032	0.272
CAN04118	NWON	0.002	0.003	0.006	0.964	0.025	0.003	0.004	0.006	0.541	0.331	0.086	0.028
CAN04119	NWON	0.004	0.005	0.009	0.892	0.091	0.004	0.005	0.009	0.384	0.404	0.099	0.095
CAN04120	NWON	0.003	0.004	0.007	0.97	0.017	0.003	0.005	0.008	0.903	0.048	0.013	0.019
CAN04121	NWON	0.004	0.005	0.006	0.949	0.036	0.003	0.005	0.008	0.296	0.013	0.648	0.027
CAN04123	NWON	0.003	0.004	0.007	0.963	0.024	0.004	0.005	0.008	0.908	0.025	0.021	0.029
CAN04124	NWON	0.002	0.003	0.005	0.983	0.008	0.002	0.003	0.005	0.912	0.065	0.005	0.008
CAN04125	NWON	0.002	0.003	0.007	0.973	0.014	0.003	0.004	0.007	0.938	0.023	0.007	0.017
CAN04126	NWON	0.004	0.006	0.042	0.938	0.01	0.005	0.009	0.064	0.812	0.094	0.007	0.009
CAN04128	NWON	0.222	0.579	0.018	0.123	0.058	0.518	0.25	0.016	0.056	0.019	0.109	0.033
CAN04129	NWON	0.919	0.03	0.006	0.034	0.011	0.893	0.055	0.005	0.024	0.008	0.007	0.008
CAN04130	NWON	0.859	0.086	0.006	0.04	0.01	0.825	0.118	0.005	0.032	0.007	0.005	0.008
CAN04131	NWON	0.825	0.139	0.007	0.022	0.007	0.8	0.16	0.006	0.015	0.007	0.007	0.005
CAN04132	NWON	0.911	0.054	0.006	0.024	0.006	0.869	0.093	0.005	0.017	0.006	0.005	0.005
CAN04134	NWON	0.922	0.046	0.008	0.019	0.005	0.889	0.076	0.007	0.013	0.006	0.005	0.004
CAN04135	NWON	0.003	0.003	0.005	0.978	0.011	0.003	0.004	0.005	0.931	0.021	0.016	0.02
CAN04136	NWON	0.056	0.029	0.017	0.881	0.016	0.122	0.038	0.02	0.71	0.085	0.008	0.017
CAN04137	NWON	0.003	0.003	0.004	0.982	0.008	0.003	0.003	0.004	0.965	0.011	0.006	0.008
CAN04138	NWON	0.011	0.007	0.007	0.967	0.009	0.024	0.012	0.01	0.529	0.324	0.091	0.01
CAN04139	NWON	0.006	0.006	0.017	0.961	0.009	0.008	0.009	0.02	0.89	0.056	0.007	0.009
CAN04140	NWON	0.003	0.005	0.011	0.972	0.009	0.003	0.006	0.012	0.935	0.03	0.006	0.008
CAN04141	NWON	0.002	0.003	0.005	0.98	0.009	0.003	0.004	0.005	0.926	0.033	0.019	0.009
CAN04142	NWON	0.002	0.004	0.007	0.962	0.024	0.003	0.005	0.009	0.701	0.196	0.024	0.062
CAN04145	NWON	0.003	0.004	0.055	0.929	0.009	0.005	0.007	0.138	0.696	0.139	0.007	0.009

Table A4 continued

Sample	Location	P_I1	P_I2	P_I3	P_I4	P_I5	P_F1	P_F2	P_F3	P_F4	P_F5	P_F6	P_F7
CAN04146	NWON	0.009	0.005	0.004	0.934	0.049	0.015	0.007	0.004	0.634	0.084	0.196	0.059
CAN04147	NWON	0.004	0.003	0.005	0.982	0.006	0.004	0.004	0.006	0.957	0.016	0.007	0.006
CAN04148	NWON	0.006	0.006	0.006	0.778	0.205	0.007	0.006	0.006	0.251	0.213	0.356	0.16
CAN04149	NWON	0.004	0.003	0.005	0.929	0.059	0.008	0.005	0.006	0.753	0.062	0.059	0.106
CAN04152	NWON	0.005	0.017	0.014	0.766	0.199	0.007	0.02	0.014	0.457	0.042	0.356	0.106
CAN04153	NWON	0.005	0.012	0.009	0.852	0.122	0.007	0.011	0.01	0.483	0.022	0.4	0.068
CAN04154	NWON	0.01	0.017	0.008	0.549	0.416	0.011	0.022	0.009	0.112	0.235	0.491	0.119
CAN04155	NWON	0.004	0.013	0.016	0.823	0.144	0.005	0.037	0.017	0.723	0.029	0.106	0.082
CAN04156	NWON	0.005	0.01	0.039	0.8	0.146	0.006	0.014	0.055	0.508	0.237	0.056	0.124
CAN04157	NWON	0.003	0.003	0.003	0.886	0.105	0.004	0.003	0.004	0.832	0.019	0.034	0.104
CAN04158	NWON	0.004	0.006	0.012	0.961	0.016	0.005	0.007	0.019	0.896	0.035	0.008	0.03
CAN04159	NWON	0.003	0.005	0.016	0.952	0.023	0.004	0.008	0.026	0.709	0.196	0.02	0.038
CAN04160	NWON	0.005	0.006	0.015	0.962	0.011	0.008	0.008	0.054	0.268	0.289	0.366	0.008
CAN04161	NWON	0.004	0.006	0.007	0.972	0.012	0.005	0.008	0.008	0.82	0.121	0.027	0.011
CAN04162	NWON	0.004	0.005	0.008	0.968	0.016	0.004	0.006	0.01	0.889	0.022	0.053	0.015
CAN04163	NWON	0.009	0.012	0.006	0.929	0.044	0.012	0.019	0.006	0.391	0.251	0.282	0.038
CAN04164	NWON	0.002	0.003	0.004	0.981	0.009	0.003	0.004	0.004	0.948	0.023	0.011	0.007
CAN04165	NWON	0.003	0.003	0.006	0.979	0.009	0.003	0.004	0.006	0.961	0.014	0.005	0.008
CAN04168	NWON	0.003	0.003	0.005	0.896	0.093	0.004	0.004	0.005	0.842	0.012	0.03	0.103
CAN04169	NWON	0.003	0.004	0.009	0.966	0.019	0.004	0.004	0.01	0.816	0.017	0.133	0.015
CAN04172	NWON	0.002	0.004	0.005	0.969	0.019	0.003	0.005	0.006	0.851	0.077	0.037	0.02
CAN04173	NWON	0.005	0.008	0.049	0.924	0.014	0.008	0.011	0.074	0.745	0.138	0.01	0.014
CAN04174	NWON	0.017	0.025	0.022	0.466	0.469	0.019	0.022	0.016	0.203	0.321	0.007	0.41
CAN04175	NWON	0.014	0.022	0.043	0.899	0.022	0.014	0.015	0.016	0.217	0.712	0.012	0.014
CAN04176	NWON	0.002	0.005	0.071	0.913	0.009	0.003	0.008	0.101	0.789	0.078	0.009	0.012
CAN04185	NWON	0.272	0.018	0.01	0.636	0.064	0.198	0.011	0.008	0.143	0.595	0.015	0.03
CAN04186	NWON	0.008	0.005	0.008	0.4	0.579	0.01	0.006	0.009	0.264	0.143	0.019	0.55
CAN04467	NWON	0.006	0.016	0.379	0.37	0.229	0.007	0.016	0.447	0.243	0.076	0.012	0.199
CAN04480	NWON	0.017	0.042	0.06	0.77	0.112	0.026	0.055	0.07	0.715	0.02	0.011	0.103
CAN04481	NWON	0.095	0.044	0.042	0.574	0.245	0.147	0.053	0.027	0.36	0.208	0.013	0.191

Table A4 continued

Sample	Location	P_I1	P_I2	P_I3	P_I4	P_I5	P_F1	P_F2	P_F3	P_F4	P_F5	P_F6	P_F7
CAN04496	NWON	0.009	0.007	0.023	0.941	0.02	0.013	0.015	0.039	0.82	0.078	0.011	0.023
CAN04611	NWON	0.084	0.022	0.027	0.803	0.065	0.147	0.023	0.023	0.411	0.324	0.028	0.044
CAN04612	NWON	0.009	0.059	0.084	0.817	0.031	0.014	0.105	0.094	0.497	0.23	0.019	0.041
CAN05260	NWON	0.004	0.006	0.008	0.958	0.024	0.005	0.008	0.009	0.91	0.038	0.007	0.024
CAN03822	MI	0.002	0.006	0.038	0.947	0.007	0.003	0.007	0.036	0.932	0.009	0.006	0.007
CAN03823	MI	0.004	0.003	0.005	0.977	0.01	0.005	0.004	0.005	0.944	0.02	0.012	0.01
CAN03824	MI	0.02	0.069	0.033	0.846	0.033	0.023	0.12	0.034	0.759	0.023	0.012	0.03
CAN03825	MI	0.003	0.004	0.005	0.961	0.028	0.005	0.005	0.005	0.682	0.034	0.242	0.027
CAN03826	MI	0.006	0.009	0.006	0.872	0.107	0.007	0.012	0.006	0.751	0.068	0.021	0.135
CAN03827	MI	0.004	0.007	0.007	0.968	0.015	0.004	0.008	0.006	0.933	0.026	0.007	0.016
CAN03828	MI	0.01	0.021	0.061	0.89	0.018	0.018	0.031	0.077	0.535	0.3	0.023	0.016
CAN03829	MI	0.005	0.005	0.011	0.957	0.022	0.008	0.008	0.014	0.828	0.076	0.042	0.025
CAN03830	MI	0.005	0.008	0.015	0.963	0.009	0.006	0.009	0.015	0.941	0.016	0.005	0.008
CAN03831	MI	0.005	0.008	0.009	0.97	0.008	0.006	0.009	0.009	0.949	0.015	0.004	0.008
CAN03832	MI	0.004	0.003	0.005	0.977	0.012	0.004	0.004	0.005	0.905	0.014	0.058	0.01
CAN03833	MI	0.004	0.008	0.01	0.972	0.007	0.005	0.011	0.01	0.824	0.137	0.007	0.006
CAN03834	MI	0.022	0.009	0.018	0.9	0.05	0.037	0.013	0.02	0.634	0.217	0.007	0.073
CAN03835	MI	0.005	0.004	0.005	0.974	0.012	0.006	0.004	0.006	0.885	0.08	0.006	0.013
CAN03836	MI	0.006	0.008	0.018	0.958	0.009	0.01	0.012	0.022	0.708	0.23	0.009	0.009
CAN03837	MI	0.002	0.003	0.005	0.982	0.008	0.003	0.003	0.005	0.816	0.157	0.008	0.008
CAN03838	MI	0.004	0.005	0.008	0.976	0.008	0.005	0.006	0.008	0.947	0.019	0.007	0.008
CAN03839	MI	0.003	0.005	0.009	0.973	0.01	0.003	0.006	0.008	0.958	0.01	0.006	0.009
CAN03840	MI	0.002	0.003	0.006	0.98	0.009	0.002	0.003	0.005	0.965	0.012	0.004	0.008
CAN03841	MI	0.002	0.004	0.007	0.979	0.008	0.003	0.006	0.007	0.952	0.016	0.008	0.008
CAN03842	MI	0.005	0.006	0.008	0.965	0.016	0.007	0.008	0.009	0.877	0.061	0.02	0.017
CAN03843	MI	0.004	0.003	0.003	0.983	0.007	0.004	0.003	0.003	0.962	0.017	0.004	0.007
CAN03844	MI	0.003	0.003	0.003	0.983	0.008	0.003	0.003	0.003	0.961	0.017	0.004	0.008
CAN03845	MI	0.003	0.003	0.004	0.934	0.055	0.004	0.004	0.005	0.842	0.019	0.072	0.054
CAN03846	MI	0.009	0.005	0.006	0.966	0.014	0.011	0.006	0.006	0.931	0.019	0.013	0.013
CAN03847	MI	0.009	0.007	0.006	0.932	0.046	0.019	0.011	0.007	0.654	0.083	0.172	0.054

Table A4 continued

Sample	Location	P_I1	P_I2	P_I3	P_I4	P_I5	P_F1	P_F2	P_F3	P_F4	P_F5	P_F6	P_F7
CAN03848	MI	0.004	0.007	0.011	0.971	0.008	0.005	0.01	0.012	0.918	0.039	0.009	0.007
CAN03849	MI	0.002	0.003	0.005	0.982	0.008	0.002	0.004	0.005	0.959	0.014	0.008	0.008
CAN03850	MI	0.006	0.008	0.009	0.962	0.015	0.007	0.011	0.008	0.815	0.131	0.012	0.015
CAN03851	MI	0.005	0.004	0.007	0.974	0.009	0.007	0.006	0.007	0.864	0.099	0.006	0.01
CAN03852	MI	0.003	0.004	0.004	0.983	0.007	0.003	0.004	0.004	0.931	0.048	0.005	0.005
CAN03853	MI	0.004	0.004	0.007	0.977	0.007	0.006	0.006	0.008	0.844	0.117	0.012	0.007
CAN03854	MI	0.008	0.007	0.012	0.956	0.017	0.013	0.009	0.014	0.821	0.096	0.027	0.019
CAN03855	MI	0.003	0.004	0.005	0.974	0.014	0.003	0.005	0.005	0.943	0.023	0.007	0.014
CAN03856	MI	0.002	0.003	0.009	0.97	0.015	0.003	0.004	0.01	0.851	0.107	0.009	0.016
CAN03857	MI	0.004	0.005	0.014	0.968	0.01	0.005	0.006	0.014	0.925	0.037	0.004	0.009
CAN03858	MI	0.004	0.008	0.012	0.97	0.006	0.005	0.013	0.013	0.801	0.154	0.009	0.005
CAN03859	MI	0.003	0.006	0.005	0.977	0.008	0.004	0.008	0.005	0.94	0.028	0.008	0.008
CAN03860	MI	0.003	0.004	0.007	0.98	0.006	0.004	0.006	0.007	0.953	0.018	0.006	0.006
CAN03861	MI	0.002	0.003	0.004	0.973	0.017	0.003	0.004	0.004	0.944	0.018	0.01	0.017
CAN03862	MI	0.003	0.003	0.004	0.982	0.008	0.004	0.004	0.004	0.866	0.013	0.103	0.007
CAN03863	MI	0.003	0.003	0.004	0.984	0.006	0.004	0.004	0.004	0.9	0.022	0.061	0.005
CAN03864	MI	0.002	0.004	0.009	0.976	0.009	0.002	0.005	0.008	0.955	0.012	0.009	0.009
CAN03865	MI	0.004	0.005	0.009	0.973	0.009	0.006	0.007	0.009	0.932	0.028	0.009	0.008
CAN03866	MI	0.003	0.007	0.014	0.965	0.011	0.004	0.009	0.017	0.922	0.02	0.015	0.013
CAN03867	MI	0.007	0.007	0.01	0.963	0.012	0.011	0.011	0.012	0.745	0.196	0.011	0.015
CAN03868	MI	0.002	0.003	0.008	0.978	0.009	0.002	0.004	0.007	0.95	0.024	0.004	0.008
CAN03869	MI	0.003	0.006	0.005	0.979	0.007	0.004	0.007	0.005	0.936	0.031	0.01	0.007
CAN03870	MI	0.007	0.015	0.051	0.877	0.05	0.011	0.022	0.064	0.703	0.122	0.013	0.065
CAN03871	MI	0.008	0.006	0.009	0.952	0.024	0.014	0.009	0.011	0.778	0.141	0.018	0.029
CAN03872	MI	0.004	0.004	0.006	0.937	0.05	0.005	0.005	0.006	0.811	0.094	0.014	0.064
CAN03873	MI	0.003	0.003	0.011	0.975	0.008	0.004	0.004	0.012	0.792	0.175	0.004	0.008
CAN04874	MI	0.003	0.003	0.009	0.974	0.011	0.004	0.005	0.01	0.858	0.099	0.012	0.012
CAN04875	MI	0.006	0.008	0.009	0.963	0.013	0.008	0.011	0.009	0.829	0.122	0.006	0.015
CAN04876	MI	0.003	0.015	0.011	0.965	0.006	0.003	0.019	0.012	0.938	0.011	0.011	0.006
CAN04877	MI	0.002	0.006	0.142	0.837	0.013	0.003	0.008	0.146	0.789	0.03	0.01	0.013

Table A4 continued

Sample	Location	P_I1	P_I2	P_I3	P_I4	P_I5	P_F1	P_F2	P_F3	P_F4	P_F5	P_F6	P_F7
CAN04878	MI	0.003	0.004	0.006	0.961	0.027	0.003	0.005	0.008	0.852	0.073	0.023	0.035
CAN04879	MI	0.004	0.009	0.007	0.971	0.009	0.006	0.013	0.007	0.81	0.15	0.006	0.009
CAN04881	MI	0.002	0.004	0.009	0.979	0.005	0.002	0.005	0.008	0.967	0.009	0.005	0.005
CAN04882	MI	0.006	0.012	0.01	0.966	0.007	0.008	0.02	0.01	0.698	0.251	0.008	0.006
CAN04883	MI	0.004	0.007	0.098	0.884	0.007	0.005	0.008	0.13	0.773	0.064	0.013	0.007
CAN04885	MI	0.003	0.004	0.01	0.935	0.048	0.006	0.007	0.012	0.775	0.058	0.04	0.102
CAN04888	MI	0.003	0.004	0.006	0.979	0.008	0.004	0.006	0.006	0.893	0.076	0.007	0.008
CAN04892	MI	0.003	0.008	0.017	0.96	0.012	0.003	0.01	0.034	0.877	0.021	0.032	0.024
CAN04897	MI	0.005	0.008	0.01	0.965	0.012	0.007	0.01	0.011	0.896	0.049	0.015	0.011
CAN04899	MI	0.008	0.014	0.04	0.893	0.046	0.014	0.022	0.049	0.79	0.043	0.026	0.057
CAN04902	MI	0.005	0.012	0.036	0.228	0.719	0.007	0.015	0.045	0.13	0.102	0.178	0.521
CAN04908	MI	0.002	0.003	0.011	0.978	0.006	0.002	0.003	0.01	0.967	0.008	0.003	0.006
CAN04909	MI	0.007	0.004	0.005	0.898	0.086	0.014	0.006	0.005	0.664	0.071	0.105	0.136
CAN04911	MI	0.003	0.004	0.006	0.982	0.006	0.004	0.004	0.006	0.927	0.034	0.019	0.005
CAN04912	MI	0.003	0.006	0.011	0.969	0.01	0.004	0.008	0.012	0.924	0.008	0.035	0.01
CAN04913	MI	0.003	0.003	0.005	0.98	0.009	0.003	0.005	0.006	0.931	0.015	0.031	0.009
CAN04914	MI	0.005	0.009	0.02	0.953	0.012	0.008	0.014	0.025	0.657	0.27	0.013	0.014
CAN04919	MI	0.019	0.414	0.07	0.296	0.201	0.024	0.441	0.03	0.185	0.185	0.013	0.121
CAN04920	MI	0.017	0.019	0.03	0.913	0.02	0.028	0.033	0.04	0.83	0.043	0.008	0.018
CAN04921	MI	0.004	0.004	0.02	0.96	0.012	0.005	0.005	0.018	0.797	0.155	0.006	0.013
CAN04922	MI	0.002	0.003	0.004	0.981	0.009	0.003	0.004	0.004	0.959	0.016	0.005	0.01
CAN04923	MI	0.004	0.005	0.006	0.978	0.008	0.005	0.006	0.005	0.952	0.018	0.007	0.007
CAN04924	MI	0.004	0.014	0.008	0.968	0.006	0.004	0.017	0.009	0.923	0.011	0.03	0.005
CAN04925	MI	0.003	0.004	0.006	0.975	0.012	0.003	0.006	0.007	0.929	0.021	0.019	0.015
CAN04926	MI	0.004	0.004	0.005	0.973	0.015	0.004	0.005	0.005	0.919	0.015	0.036	0.015
CAN04927	MI	0.002	0.007	0.033	0.947	0.012	0.002	0.008	0.032	0.892	0.048	0.007	0.011
CAN04928	MI	0.002	0.011	0.012	0.965	0.01	0.003	0.016	0.017	0.908	0.043	0.005	0.009
CAN04929	MI	0.003	0.004	0.015	0.97	0.008	0.003	0.005	0.014	0.945	0.02	0.007	0.007
CAN04930	MI	0.003	0.003	0.003	0.954	0.038	0.003	0.003	0.003	0.907	0.016	0.027	0.04
CAN04931	MI	0.006	0.008	0.017	0.96	0.01	0.009	0.011	0.02	0.794	0.142	0.016	0.008

Table A4 continued

Sample	Location	P_I1	P_I2	P_I3	P_I4	P_I5	P_F1	P_F2	P_F3	P_F4	P_F5	P_F6	P_F7
CAN04932	MI	0.003	0.004	0.007	0.972	0.013	0.004	0.007	0.009	0.793	0.159	0.01	0.017
CAN05268	MI	0.018	0.823	0.018	0.118	0.022	0.029	0.799	0.014	0.096	0.03	0.009	0.022
CAN05269	MI	0.022	0.876	0.02	0.054	0.028	0.037	0.837	0.018	0.029	0.023	0.038	0.018
CAN05270	MI	0.003	0.008	0.056	0.923	0.01	0.003	0.01	0.05	0.897	0.026	0.005	0.009
CAN04864	WI	0.002	0.003	0.007	0.978	0.009	0.002	0.004	0.007	0.401	0.571	0.005	0.009
CAN04865	WI	0.859	0.057	0.017	0.052	0.016	0.841	0.073	0.018	0.031	0.014	0.007	0.016
CAN04866	WI	0.704	0.156	0.045	0.088	0.007	0.776	0.123	0.027	0.044	0.014	0.01	0.005
CAN04933	WI	0.003	0.012	0.013	0.96	0.012	0.004	0.033	0.018	0.917	0.013	0.004	0.011
CAN04934	WI	0.005	0.006	0.013	0.966	0.011	0.007	0.008	0.016	0.918	0.031	0.008	0.012
CAN04935	WI	0.004	0.003	0.004	0.983	0.007	0.004	0.004	0.004	0.946	0.029	0.005	0.007
CAN04936	WI	0.002	0.004	0.007	0.981	0.005	0.003	0.005	0.007	0.682	0.293	0.006	0.004
CAN04937	WI	0.007	0.007	0.007	0.957	0.022	0.011	0.011	0.008	0.84	0.096	0.008	0.026
CAN04938	WI	0.005	0.007	0.006	0.976	0.007	0.007	0.008	0.005	0.935	0.035	0.005	0.006
CAN04939	WI	0.01	0.01	0.01	0.952	0.018	0.02	0.016	0.012	0.805	0.092	0.035	0.02
CAN04940	WI	0.003	0.005	0.01	0.938	0.045	0.004	0.006	0.011	0.835	0.07	0.011	0.064
CAN04941	WI	0.002	0.004	0.015	0.971	0.008	0.003	0.005	0.018	0.935	0.024	0.006	0.008
CAN04942	WI	0.003	0.004	0.008	0.98	0.006	0.003	0.005	0.008	0.958	0.017	0.003	0.005
CAN04943	WI	0.003	0.003	0.01	0.953	0.031	0.004	0.004	0.012	0.81	0.12	0.018	0.031
CAN04944	WI	0.002	0.004	0.003	0.76	0.231	0.002	0.005	0.003	0.701	0.014	0.008	0.266
CAN04945	WI	0.002	0.017	0.013	0.959	0.008	0.003	0.025	0.019	0.899	0.04	0.006	0.008
CAN04946	WI	0.004	0.006	0.008	0.972	0.01	0.005	0.007	0.007	0.947	0.017	0.007	0.009
CAN04947	WI	0.003	0.003	0.004	0.984	0.006	0.003	0.003	0.003	0.968	0.012	0.003	0.006
CAN04948	WI	0.003	0.004	0.004	0.979	0.01	0.004	0.004	0.004	0.947	0.019	0.011	0.011
CAN04949	WI	0.005	0.005	0.004	0.947	0.04	0.006	0.006	0.004	0.789	0.036	0.126	0.033
CAN04950	WI	0.003	0.007	0.01	0.969	0.01	0.004	0.011	0.013	0.878	0.013	0.071	0.011
CAN04951	WI	0.003	0.005	0.015	0.968	0.009	0.004	0.006	0.015	0.952	0.011	0.005	0.008
CAN04952	WI	0.002	0.003	0.003	0.975	0.017	0.002	0.003	0.003	0.95	0.01	0.015	0.017
CAN04953	WI	0.002	0.004	0.016	0.969	0.008	0.003	0.004	0.016	0.953	0.012	0.005	0.008
CAN04954	WI	0.003	0.004	0.004	0.983	0.006	0.004	0.005	0.005	0.938	0.027	0.015	0.005
CAN04955	WI	0.033	0.05	0.052	0.853	0.013	0.052	0.073	0.059	0.738	0.055	0.009	0.014

Table A4 continued

Sample	Location	P_I1	P_I2	P_I3	P_I4	P_I5	P_F1	P_F2	P_F3	P_F4	P_F5	P_F6	P_F7
CAN04956	WI	0.005	0.004	0.007	0.973	0.011	0.006	0.005	0.007	0.955	0.01	0.007	0.01
CAN04957	WI	0.008	0.004	0.013	0.958	0.017	0.011	0.006	0.016	0.907	0.034	0.009	0.017
CAN04958	WI	0.003	0.004	0.006	0.983	0.005	0.003	0.005	0.006	0.945	0.03	0.005	0.004
CAN04959	WI	0.005	0.005	0.019	0.946	0.026	0.007	0.006	0.026	0.879	0.033	0.023	0.027
CAN04960	WI	0.004	0.005	0.006	0.968	0.017	0.005	0.007	0.008	0.931	0.017	0.007	0.025
CAN04961	WI	0.012	0.006	0.024	0.906	0.051	0.018	0.008	0.044	0.47	0.389	0.014	0.057
CAN04962	WI	0.005	0.011	0.046	0.931	0.007	0.006	0.013	0.041	0.877	0.05	0.006	0.007
CAN04963	WI	0.005	0.021	0.006	0.956	0.011	0.007	0.03	0.007	0.905	0.019	0.021	0.012
CAN04964	WI	0.005	0.008	0.1	0.879	0.008	0.007	0.011	0.105	0.821	0.032	0.017	0.007
CAN04965	WI	0.004	0.004	0.009	0.976	0.008	0.006	0.005	0.01	0.921	0.021	0.03	0.007
CAN04966	WI	0.007	0.009	0.012	0.967	0.005	0.009	0.013	0.013	0.925	0.028	0.007	0.005
CAN04967	WI	0.004	0.009	0.011	0.954	0.022	0.004	0.009	0.01	0.94	0.012	0.004	0.021
CAN04968	WI	0.004	0.008	0.006	0.976	0.006	0.006	0.011	0.007	0.94	0.022	0.008	0.006
CAN04969	WI	0.905	0.024	0.012	0.039	0.02	0.912	0.027	0.009	0.023	0.01	0.007	0.012
CAN04970	WI	0.006	0.006	0.017	0.924	0.047	0.007	0.007	0.02	0.475	0.426	0.006	0.059
CAN04971	WI	0.006	0.009	0.019	0.952	0.014	0.009	0.013	0.021	0.906	0.029	0.004	0.018
CAN04972	WI	0.818	0.014	0.01	0.11	0.048	0.828	0.012	0.007	0.036	0.029	0.067	0.02
CAN04973	WI	0.003	0.005	0.005	0.976	0.011	0.003	0.008	0.005	0.94	0.019	0.012	0.013
CAN04974	WI	0.004	0.01	0.007	0.968	0.013	0.005	0.015	0.008	0.878	0.062	0.016	0.016
CAN04975	WI	0.104	0.811	0.027	0.047	0.01	0.218	0.681	0.032	0.046	0.009	0.004	0.009
CAN04976	WI	0.006	0.007	0.009	0.675	0.304	0.006	0.008	0.009	0.737	0.065	0.01	0.165
CAN05261	WI	0.005	0.006	0.01	0.971	0.009	0.006	0.009	0.011	0.943	0.013	0.008	0.009
CAN04815	MN	0.002	0.005	0.006	0.798	0.189	0.003	0.006	0.007	0.682	0.016	0.009	0.278
CAN04816	MN	0.003	0.003	0.01	0.978	0.007	0.003	0.005	0.015	0.944	0.022	0.005	0.006
CAN04817	MN	0.008	0.009	0.027	0.947	0.01	0.015	0.015	0.043	0.861	0.014	0.044	0.009
CAN04818	MN	0.004	0.004	0.005	0.977	0.01	0.005	0.005	0.005	0.813	0.152	0.01	0.011
CAN04819	MN	0.003	0.004	0.01	0.977	0.006	0.003	0.005	0.01	0.948	0.022	0.005	0.006
CAN04820	MN	0.003	0.005	0.011	0.974	0.007	0.005	0.008	0.015	0.871	0.089	0.005	0.007
CAN04821	MN	0.003	0.003	0.009	0.976	0.009	0.003	0.004	0.009	0.946	0.021	0.009	0.008
CAN04822	MN	0.002	0.003	0.009	0.978	0.008	0.002	0.004	0.01	0.942	0.026	0.008	0.008

Table A4 continued

Sample	Location	P_I1	P_I2	P_I3	P_I4	P_I5	P_F1	P_F2	P_F3	P_F4	P_F5	P_F6	P_F7
CAN04823	MN	0.004	0.004	0.011	0.973	0.008	0.005	0.005	0.011	0.937	0.024	0.009	0.008
CAN04824	MN	0.003	0.004	0.005	0.98	0.009	0.003	0.004	0.005	0.957	0.015	0.008	0.008
CAN04825	MN	0.002	0.007	0.019	0.964	0.008	0.003	0.013	0.028	0.792	0.146	0.011	0.007
CAN04826	MN	0.003	0.004	0.01	0.975	0.008	0.004	0.006	0.013	0.742	0.194	0.032	0.008
CAN04827	MN	0.03	0.021	0.105	0.821	0.022	0.062	0.032	0.179	0.604	0.043	0.058	0.022
CAN04828	MN	0.002	0.005	0.006	0.979	0.007	0.003	0.006	0.006	0.963	0.012	0.004	0.007
CAN04829	MN	0.004	0.004	0.006	0.977	0.009	0.004	0.005	0.006	0.893	0.08	0.004	0.008
CAN04830	MN	0.002	0.004	0.006	0.983	0.005	0.003	0.004	0.006	0.941	0.036	0.005	0.005
CAN04831	MN	0.002	0.004	0.006	0.982	0.006	0.002	0.005	0.006	0.963	0.012	0.007	0.006
CAN04832	MN	0.002	0.004	0.005	0.981	0.008	0.003	0.005	0.005	0.967	0.01	0.004	0.007
CAN04833	MN	0.002	0.004	0.007	0.979	0.008	0.003	0.005	0.007	0.952	0.019	0.005	0.008
CAN04834	MN	0.002	0.005	0.006	0.978	0.008	0.003	0.006	0.005	0.966	0.01	0.004	0.007
CAN04835	MN	0.002	0.004	0.02	0.964	0.009	0.003	0.006	0.025	0.912	0.031	0.014	0.01
CAN04836	MN	0.005	0.01	0.034	0.937	0.015	0.007	0.013	0.042	0.883	0.016	0.026	0.013
CAN04837	MN	0.002	0.003	0.006	0.981	0.008	0.003	0.004	0.007	0.833	0.024	0.122	0.008
CAN04838	MN	0.003	0.004	0.014	0.96	0.018	0.004	0.006	0.018	0.878	0.041	0.021	0.032
CAN04839	MN	0.003	0.006	0.021	0.961	0.009	0.005	0.009	0.031	0.839	0.081	0.027	0.009
CAN04840	MN	0.005	0.009	0.006	0.961	0.019	0.008	0.013	0.007	0.917	0.022	0.006	0.026
CAN04841	MN	0.003	0.006	0.006	0.967	0.017	0.005	0.009	0.007	0.924	0.024	0.007	0.022
CAN04842	MN	0.004	0.004	0.006	0.973	0.014	0.005	0.005	0.006	0.866	0.094	0.008	0.015
CAN04843	MN	0.007	0.017	0.021	0.95	0.006	0.009	0.024	0.026	0.88	0.034	0.022	0.005
CAN04844	MN	0.002	0.004	0.007	0.982	0.005	0.002	0.004	0.007	0.957	0.018	0.007	0.005
CAN04845	MN	0.002	0.006	0.005	0.976	0.011	0.002	0.007	0.005	0.96	0.01	0.005	0.011
CAN04846	MN	0.009	0.013	0.063	0.822	0.093	0.013	0.019	0.048	0.731	0.021	0.005	0.163
CAN04847	MN	0.005	0.004	0.02	0.959	0.013	0.012	0.007	0.051	0.789	0.118	0.012	0.011
CAN04848	MN	0.004	0.009	0.008	0.964	0.016	0.009	0.028	0.01	0.712	0.12	0.102	0.019
CAN04849	MN	0.006	0.009	0.014	0.876	0.095	0.017	0.025	0.026	0.442	0.252	0.102	0.135
CAN04850	MN	0.003	0.009	0.027	0.933	0.028	0.007	0.022	0.042	0.659	0.032	0.215	0.023
CAN04851	MN	0.005	0.01	0.023	0.789	0.174	0.009	0.018	0.033	0.365	0.163	0.267	0.145
CAN04852	MN	0.002	0.004	0.01	0.978	0.006	0.003	0.004	0.01	0.962	0.012	0.004	0.005

Table A4 continued

Sample	Location	P_I1	P_I2	P_I3	P_I4	P_I5		P_F1	P_F2	P_F3	P_F4	P_F5	P_F6	P_F7
CAN04853	MN	0.003	0.004	0.008	0.98	0.005		0.004	0.006	0.008	0.943	0.023	0.012	0.005
CAN04854	MN	0.002	0.004	0.008	0.98	0.006		0.002	0.005	0.008	0.802	0.17	0.007	0.006
CAN04855	MN	0.003	0.004	0.011	0.966	0.016		0.003	0.006	0.012	0.852	0.061	0.021	0.046
CAN04856	MN	0.003	0.003	0.009	0.975	0.009		0.003	0.004	0.009	0.953	0.016	0.005	0.009
CAN04857	MN	0.003	0.004	0.012	0.964	0.017		0.004	0.006	0.015	0.926	0.021	0.011	0.018
CAN04858	MN	0.003	0.003	0.011	0.934	0.049		0.004	0.004	0.013	0.769	0.078	0.064	0.068
CAN04859	MN	0.002	0.003	0.004	0.983	0.007		0.003	0.004	0.005	0.895	0.02	0.066	0.007
CAN04860	MN	0.002	0.003	0.006	0.983	0.007		0.002	0.004	0.006	0.891	0.076	0.014	0.006
CAN04861	MN	0.007	0.006	0.016	0.961	0.01		0.015	0.012	0.028	0.888	0.022	0.026	0.01
CAN04862	MN	0.003	0.005	0.011	0.974	0.008		0.003	0.006	0.01	0.949	0.019	0.005	0.007
CAN04863	MN	0.002	0.004	0.026	0.962	0.006		0.003	0.005	0.031	0.922	0.026	0.007	0.005
CAN05256	MN	0.837	0.08	0.011	0.051	0.02		0.863	0.07	0.008	0.034	0.009	0.005	0.012
CAN05257	MN	0.033	0.834	0.009	0.08	0.043		0.064	0.808	0.007	0.062	0.017	0.013	0.03
CAN05258	MN	0.031	0.894	0.005	0.053	0.018		0.047	0.858	0.004	0.035	0.026	0.011	0.018
CAN05259	MN	0.014	0.939	0.012	0.028	0.008		0.023	0.922	0.011	0.019	0.012	0.007	0.007