COSEWIC Report

Designatable Units for Caribou (*Rangifer tarandus*) in Canada

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

This report may be cited as follows:

COSEWIC. 2011. Designatable Units for Caribou (*Rangifer tarandus*) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 88 pp.

Production note:

COSEWIC acknowledges Laura Finnegan, Laura Thompson, and Paul Wilson for writing the special report on the Designatable Units for caribou in Canada prepared under contract with Environment Canada. The contractors' involvement with the writing of the special report ended with the acceptance of the provisional report. Any subsequent modifications to the special report were overseen by Justina Ray with Graham Forbes, Jeff Bowman, Chris Johnson, and Ian Thompson of the COSEWIC Terrestrial Mammals Specialist Subcommittee.

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PREFACE

This report represents the Designatable Unit (DU) component of a Status Report on Caribou (*Rangifer tarandus*) in Canada. In preparation for upcoming assessments (and reassessments) of this species, a clear and consistent scheme for identifying DUs is needed. Due to the complexity inherent in this species, the Terrestrial Mammals Specialist Subcommittee (SSC) has elected to separate the approval of the DUs from the status assessment process.

Similar to any COSEWIC Status Report, this report underwent two jurisdictional reviews and one review by COSEWIC. The report was also reviewed by a number of caribou experts and other individuals familiar with application of the DU concept.

The Terrestrial Mammals SSC presented the report to COSEWIC at the November 2011 WSAM, when COSEWIC voted to adopt the proposed DU structure for Caribou in Canada. COSEWIC will begin the process of assessing all extant DUs in 2012; if changes in any DUs are warranted, COSEWIC will vote on the particular DU at that time.

EXECUTIVE SUMMARY

Over their circumpolar distribution in boreal, montane, and arctic environments, caribou (*Rangifer tarandus*) exhibit tremendous variation in ecology, genetics, behaviour and morphology. Within North America the majority of the range of this medium-sized ungulate occurs in Canada. Currently, only one species of caribou (or reindeer in Europe and Asia) is recognized world-wide. Although prevailing taxonomy recognizes four native extant and one extinct subspecies in North America, it is out-of-date with respect to current science and does not capture the variability of caribou across their range in Canada. Ecotypic designations that broadly describe adaptive behaviours have been used increasingly to classify caribou populations according to life-history strategies and ecological conditions, but are themselves inconsistently applied and have no universally recognized nomenclature. COSEWIC's Designatable Units are recognized as both discrete and significant units that are irreplaceable components of Canada's biodiversity. Although caribou population ranges are the most common unit for management or recovery activities, DUs are usually comprised of multiple populations. Canada's Species At Risk Act (SARA) recognizes that entities below the species level require conservation, and provides COSEWIC the mandate to assess them. The last COSEWIC assessments for caribou were conducted in 2004; eight "nationally significant populations" have been assessed to date and are currently recognized. Many northern populations have never been assessed by COSEWIC.

To establish the long-term biological foundations for the conservation and management of caribou in Canada, COSEWIC undertook a special project to define the DUs for future status assessments and reassessments of this species. We used five principal lines of evidence to identify DUs for caribou, based on COSEWIC guidelines. Starting with known distinct subspecies, ecotypes, or natural population groupings, we examined available evidence on phylogenetics, genetic diversity and structure, morphology, movements, behaviour and life

history strategies, and distribution for each. We evaluated whether such units were significantly discrete from neighbouring units. We then determined if the discrete units differed significantly according to a set of evolutionary criteria. We also determined whether currently recognized groups of caribou (e.g., taxonomy) should be further divided into separate DUs.

All studies that examined sources of variation (e.g., genetics) have been limited in geographic scope, making it impossible to undertake comprehensive comparisons across the entire range of the species in Canada. Because some criteria for both discreteness and significance offered stronger evidence than others, DU decisions were generally made on multiple lines of evidence.

Based on the COSEWIC DU criteria for discreteness and significance we propose 12 DUs for caribou in Canada. These are: Peary caribou in the Arctic Archipelago (DU1), Dolphin-Union caribou of Victoria Island (DU2), Barren-ground caribou of northern and northwest Canada (DU3), Eastern Migratory caribou of northern Labrador, Québec, Ontario, and Manitoba (DU4), Newfoundland caribou (DU5), Boreal caribou occurring in the boreal forest from British Columbia and the Northwest Territories to Labrador (DU6), Northern Mountain caribou of British Columbia, Yukon and Northwest Territories (DU7), Central Mountain caribou of central British Columbia and Alberta (DU8), Southern Mountain caribou of southern British Columbia (DU9), Torngat Mountain caribou of northern Québec and Labrador (DU10), Atlantic-Gaspésie caribou, the remnant of a formerly continuous population across the Gaspé Peninsula, the Maritimes, and northern New England (DU11), and Dawson's caribou, which disappeared from Haida Gwaii in the 1920s (DU12). All 8 pre-existing "Nationally Significant Populations" were maintained, although the boundaries of two (Northern Mountain [DU7] and Southern Mountain [DU9]) were modified significantly. Four new DUs were created, three of which included caribou populations that have never been assessed by COSEWIC, and a fourth (Central Mountain [DU8]), which included populations that had been previously assessed as DU9.

As would be expected of this broadly-distributed species, almost all evidence used to assess the discreteness and significance of each DU was from portions of Canada, making cross-comparisons of all DUs across the country generally impossible. There are a number of areas and populations for which data are meagre. The foundation of all DU designations was related to the diversity of ecological settings across the range of this species, to which populations have adapted, at least behaviourally. Genetic information provided mixed support: while genetic studies were used to support the discreteness of most DUs, phylogenetic evidence was more equivocal. DU designations were made when several lines of evidence provided collective support for their discreteness and significance. The majority of these 12 DUs met at least two criteria each for discreteness and significance.

We identified research gaps in caribou ecology, morphology and genetics that could inform the conservation of this species across its extensive range in Canada and help resolve existing questions about the origin and divergence of existing populations as well as taxonomic designation at the subspecies level.

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INTRODUCTION

Effective species conservation and management not only requires attention to the species themselves, but also to the diversity within a species. Across the range of a species, individuals may display considerable morphological, genetic, and behavioural variability reflective of both plasticity and adaptation to local environments. Although such heterogeneity has been long recognised, defining the scale at which to provide protection remains problematic. COSEWIC's Designatable Unit (DU) concept acknowledges that there are spatially, ecologically or genetically discrete and evolutionarily significant units that are irreplaceable components of biodiversity. SARA recognizes that entities below the species level require conservation, and provides COSEWIC the mandate to assess them. The process of designating DUs takes into account established taxonomy, phylogenetics, genetics, morphology, life history and behaviour of the species, as well as biogeographical information such as range disjunction and the eco-geography in which the species is found.

Caribou (Order: Artiodactyla, Family: Cervidae, Subfamily: Capreolinae, Genus: Rangifer, Species: tarandus; Gilbert et al. 2006) are medium-sized members of the deer family . The current distribution of this species spreads across boreal, montane, and arctic environments in most Canadian Provinces and all Territories, except New Brunswick, Nova Scotia and Prince Edward Island. Over this broad area, caribou exhibit tremendous variability in ecology, genetics, behaviour and morphology. Although other species occur over equally large geographic areas, caribou are said to be the most widespread and variable of all the Cervidae (Geist 1998), thereby complicating efforts related to their conservation and management. Across Canada, caribou are also facing increasingly severe threats, raising the need to review their conservation status as part of the listing process under SARA (e.g., Festa-Bianchet et al. 2011).

To establish the long-term biological foundations of caribou conservation and management in Canada, COSEWIC undertook a special project to define the DUs for upcoming status assessments and reassessments of this species. Eight caribou 'populations' were assessed by COSEWIC from 2000-2003 and will require reassessments. Several entities of the species may warrant assessment for the first time, due to mounting concerns about population trends and threats. The concept of DUs has been recently formalized (COSEWIC 2009), making it timely to undertake a comprehensive classification for caribou and derive a clear and consistent scheme for identifying DUs of this complex species across all Canadian populations.

CARIBOU BIOLOGY, ECOLOGY AND DISTRIBUTION IN CANADA

Caribou males weigh 120-200 kg and females 80-140 kg, with the smallest individuals from populations in the Arctic Archipelago (Manning 1960; Bergerud 2000). Antlers are semi-palmate, and occur in both sexes, although in some populations few females have antlers. Breeding pelage is variable in colour and patterning (Geist 2007) and winter pelage varies from almost white to dark brown. Caribou are well-adapted to cold environments with dense pelage, large fat stores, a counter-current heat exchange to reduce loss of heat in respiration, and an ability to reduce energy expenditure in the winter by decreasing metabolism. They are able to digest lichens and survive on a low protein diet by recycling urea (Parker et al. 2005).

Caribou rut in late autumn and calve in late spring through early summer with the actual dates varying with latitude and environmental and physical condition (Banfield 1961; Kelsall 1968; Adams & Dale 1998). There is considerable sexual dimorphism, such that males grow until 5 or 6 years of age, whereas females often stop growing at an earlier age (i.e., after their first reproductive attempt, generally at 3 or 4 yrs). Social behaviour ranges from relatively solitary to highly gregarious, and calving strategies and migration patterns are correspondingly variable. Winter diet is dominated by arboreal and ground lichens, although caribou exploit available vegetation across diverse habitats (e.g., grasses, sedges, willow: Kelsall 1968; Russell et al. 1993; Larter & Nagy 2004; Thomas et al. 1996; Thompson & McCourt 1981). During spring, summer, and autumn, caribou forage primarily on vascular plants, although lichen and fungi are still important dietary components. Caribou are one of the primary herbivores in Arctic regions and are the only vertebrate grazers of the lichens of the tundra and taiga (Dale et al. 1994; Bergerud 2000; Mowat & Heard 2006). Caribou are a primary food source of arctic predators and human populations at certain times of the year (Mowat & Heard 2006; Musiani et al. 2007; Hummel & Ray 2008), and play a role in nutrient transfer influencing ecosystem function by virtue of their high concentrations in tundra environments (e.g., Brathen et al. 2007). The ecological role of caribou is considerably less obvious in boreal and some mountain areas, where caribou occur at much lower densities than in the Arctic and sub-Arctic.

Rangifer tarandus has the most widespread circumpolar distribution of any ungulate, occurring in an almost continuous band from 14°W to 5°E, from approximately 46^{o} to above 80°N latitude, encompassing montane environments in the south, through the boreal and across the northern limits of plant growth in the Arctic (Banfield 1961; Geist 1998; Bergerud 2000). Once ranging from Newfoundland to the Islands of Haida Gwaii in British Columbia and from southern BC to New Hampshire, caribou disappeared from the Maritimes and New England over a century ago, and their range has contracted in all provinces (Bergerud 1974; Gunn et al. 2011). Within North America, the majority of caribou currently occur in northern Canada and Alaska. In Canada, they occur south from Ellesmere Island in the high Arctic to the north shore of Lake Superior, and southwest from Yukon to the Coast Mountains of British Columbia and eastwards to Baffin Island, and across the boreal shield and tundra of Newfoundland and Labrador to northeastern BC. Caribou occur in five of the seven COSEWIC National Ecological Areas (Figure 1).

CURRENT TAXONOMY OF CARIBOU

Prior to the last formal taxonomic revision of *Rangifer* in 1961, 55 species and subspecies of caribou and reindeer had been described (Banfield 1961). Only one species of caribou (or reindeer in Europe and Asia) is recognized world-wide, ranging over northern North America, Europe and Asia. Classifying the physical, behavioural and ecological diversity of this animal below the species level, however, remains an enormous challenge. Skull measurements and pelage, but also antler shape and hoof shape, were used in Banfield's (1961) division of *Rangifer* into four extant, and one extinct North American subspecies. *R. t. groenlandicus* and *R. t. granti* are most commonly known as 'barren-ground caribou' and 'Grant's caribou', respectively, *R. t. caribou* is 'woodland', and *R. t. pearyi* is "Peary caribou' (Figure 2). Dawson's caribou or *R. t. dawsoni* once occurred in the Haida Gwaii islands of BC (Byun et al. 2002).

European reindeer have been introduced in several places in Canada (Newfoundland, Anticosti Island, Great Slave Lake, Belcher Islands, Baffin Island, and the Mackenzie Delta) with the aim of promoting husbandry, but never with as much success as in neighbouring Alaska (Scotter 1972; Stager 1984). In most places transplants were unsuccessful; the sole exception is in the Mackenzie Delta region of the Northwest Territories, where a population was established (Stager 1984) and then introduced to the Belcher Islands in 1978 (Ferguson 1985). Introduced reindeer will not be considered in this report, other than in cases where genetic introgression with wild caribou may have taken place.

A complete revision of the taxonomic entities within *Rangifer* is needed (Geist 2007; Gunn 2009; Couturier et al. 2009a). Banfield's (1961) subspecies classification is still used, largely because no alternative has been identified in a systematic way or has ever been broadly accepted. Other authors have placed more stress on hoof shape and antler formation, together with pelage, as diagnostic traits of subspecies (Manning 1960; Geist 1991; 1998). Not surprisingly, our collective understanding of caribou ecology, distribution, and genetics has revealed substantial diversity within Banfield's subspecies (Miller et al. 2007a). In addition, the basis for taxonomy has changed since the 1960s with an increasing shift to the use of genetics and alternative approaches to describe morphological variation. Indeed, skeletal size, skull size and shape vary with nutritional condition (Meldgaard 1986) and movement patterns (Couturier et al. 2010), and hence are likely to be inappropriate taxonomic measures for caribou (Couturier 2007). Controversy surrounding Banfield's subspecies classification has been particularly pronounced for woodland caribou (*R. t. caribou*), because it currently lumps populations into a 'catchall' category for all larger-bodied members of the species, which occur in almost every available habitat type, despite exhibiting considerable variability in behaviour, ecology, and morphology (Geist 2007).

ECOTYPES

To cope with the lack of resolution of caribou taxonomy, ecotype designations have been increasingly applied in conjunction with, or in lieu of, subspecies definitions. First proposed for caribou by Bergerud (1988), the ecotype -- a population or group of populations adapted to a particular set of environmental conditions -- is a convenient means of classifying caribou populations (also known as herds) according to different life-history strategies and ecological conditions.

Because ecotype classifications are as commonly made within *Rangifer* subspecies as as within the species at large, there is no universally accepted list of either ecotypes or criteria to distinguish ecotypes. Bergerud (1996) distinguished two general ecotypes on the basis of their calving strategies. The *sedentary* ecotype refers to populations whose females adopt a dispersed spacing behaviour to avoid predators when calving (Bergerud 1985; Bergerud et al. 1990; Bergerud et al. 2008). Sedentary caribou tend to occur at low densities and do not undertake extensive movements between seasonal ranges, although individual animals move extensively while still isolating themselves during calving season. *Migratory* caribou aggregate during calving, with some populations undertaking long-distance migrations to calving grounds situated along the coast, at higher elevations, or in bogs and fens, where they give birth in large aggregations (Kelsall 1968; Bergerud 1988, 1996; Schaefer 2003). However, it has become increasingly evident that not all caribou fall neatly into these two categories. For example, some caribou populations in the Arctic islands migrate but tend to have dispersed calving (Miller 1990) in comparison to those of the migratory populations of the central barrens (Kelsall 1968; Nagy et al. 2011). Caribou dwelling in mountainous areas of the Yukon, Northwest Territories, British Columbia, Alberta, Québec, and Labrador provide further complexity: these caribou calve at higher altitudes and move as much as 200 km between seasonal ranges (Edmonds 1988; Couturier et al. 2010; Seip & McLellan 2008).

There is confusion in ecotype terminology. For example, two different *R. t. caribou* ecotypes in Ontario are labelled ‘forest-tundra’ and ‘forest-dwelling’ (Harris 1999; OMNR 2009), while in Québec they are called ‘migratory’ and ‘sedentary’ (Boulet et al. 2007). British Columbia refers to its different ecotypes as ‘northern’, ‘mountain’ and ‘boreal’ (Heard & Vagt 1998), while in Alberta ‘mountain’ caribou have more affinity to BC's 'northern' than their 'mountain' ecotype (Edmonds 1988; McDevitt et al. 2009). Arctic-dwelling ecotypes have alternately been named ‘ultra Pearyi’, ‘Boothia Peninsula’, and ‘Arctic island’ (Miller & Gunn 2003; Miller et al. 2007b). In western Canada, it is common to refer to ecotypes of montane caribou due to the marked variability of ecological and physical factors within their ranges, such as relative depth of the snowpack, steepness and form of mountains, and available forage (Johnson et al. 2000; Stevenson et al. 2001; Terry et al. 2000; Kinley et al. 2007), leading to labels such as ‘migratory-montane’, ‘sedentary-montane’, ‘deep-snow’, and ‘shallow-snow’. The more generic ‘montane ecotype’ refers to those caribou dwelling in mountainous areas of the western Rockies or Québec-Labrador that undertake altitudinal migrations between seasons.

Calving strategy (whether dispersed or aggregated), rather than migration distance, is a key feature that differentiates caribou ecotypes, because the length of travel to and from calving areas can be highly variable between populations and even between years. For example, the large populations that calve and spend time on the tundra in summer may winter there or migrate long distances to below the treeline in winter. Regardless of the duration of migration and whether they winter on the tundra or in the forest, all exhibit aggregated calving. Tundra-wintering populations in the eastern Arctic tend to undertake shorter-distance seasonal movements than those in the west, and some of the caribou residing on arctic islands are almost entirely sedentary. Although it might appear most appropriate to apply the barren-ground moniker for all cases (the common name for the subspecies *R. t. groenlandicus*), this name fails to include the migratory populations that exhibit aggregated calving in Manitoba, Ontario, Québec, and Labrador and that are currently classified as *R. t. caribou* under the Banfield (1961) scheme.

CURRENT DU STRUCTURE OF CARIBOU IN CANADA

COSEWIC has assessed eight caribou units below the species level in Canada since 2000 (Table 1). These were known as “Nationally Significant Populations,” the predecessor to Designatable Units. Subspecies classification was used as the primary means for delineation, but *R. t. caribou* was further subdivided into “ecotypes” (COSEWIC 2002). Dolphin and Union caribou were separated from Peary caribou in the latest assessment, but were included in the same status report because they had been considered together previously (COSEWIC 2004). Seven assessments were covered in two COSEWIC status reports: the boreal, northern and southern mountain, Newfoundland, and Atlantic-Gaspésie populations (woodland caribou subspecies; COSEWIC 2002), and the caribou of the Arctic Islands (Peary caribou and the Dolphin and Union population of Barren-ground caribou'; COSEWIC 2004). Dawson’s caribou was designated as extinct by COSEWIC in 2000 (see COSEWIC 2002). The large mainland migratory populations of northern Canada and the tundra-wintering populations of the Eastern Arctic have not been assessed (Figure 3). It should be noted that COSEWIC did not use 'ecotype' in the same way just discussed here. Instead, four ecotypes of woodland caribou subspecies (COSEWIC 2002) were based on COSEWIC’s national ecological areas. Newfoundland caribou were treated separately as a "distinct population". The uncertain taxonomic status of caribou is highlighted by the exclusion of the large migratory populations of northern Manitoba, Ontario, and the Ungava Peninsula from the COSEWIC status report on the woodland caribou subspecies (COSEWIC 2002), despite those populations technically belonging to that subspecies according to Banfield (1961).

METHODS

There are multiple definitions and considerable debate about the process for differentiating ecologically significant units and management units (Fraser & Bernatchez 2001). Both types of units may play a role in the conservation and management of listed or harvested species and provide some perspective on the identification and interpretation of DUs. In this report, however, DUs are identified based on the criteria provided by COSEWIC (COSEWIC 2009): “DUs should be discrete and evolutionarily significant units of the taxonomic species, where 'significant' means that the unit is important to the evolutionary legacy of the species as a whole and if lost would likely not be replaced through natural dispersion.” When identifying DUs there is no consideration of conservation status or current or future threats to the persistence of a particular population. Furthermore, status assessment occurs at the scale of the DU and COSEWIC does not consider individual populations that are not differentiated as discrete and evolutionary units, even if they are imperilled. In a similar vein, DUs that are identified at a national scale should not distract from most management actions that for this species are often most suitably directed at the scale of the individual population.

Since the last assessments of caribou in 2004, COSEWIC has refined the definition of Designatable Unit that was confirmed by COSEWIC in 2009 (COSEWIC 2009). Establishing discreteness is the first step. Discreteness may refer to distinctiveness in genetic characteristics or inherited traits, habitat discontinuity, or ecological isolation. Significance is also included in the definition of DU as a reflection of the opinion that isolation alone is insufficient for designation. Evolutionary significance may apply when there is: 1) deep phylogenetic divergence (e.g., glacial races), 2) evidence that the population persists in a unique ecological setting that has likely given rise to local adaptations, or 3) when there is only one natural surviving occurrence in a particular ecological setting.

DETERMINING PUTATIVE DESIGNATABLE UNITS

COSEWIC's (2009) guidelines for the identification of DUs explicitly recognize that DUs can be based on named subspecies or varieties. In light of the above discussion, however, the current subspecies classification for caribou is widely regarded as antiquated and inaccurate across some parts of the species' range. Even more relevant for this discussion, some subspecies (particularly *R. t. caribou*) do not capture the variability displayed by caribou across their range in Canada. While ecotypes have been more widely applied to describe types of caribou in relation to their environment, the lack of a universally recognized system to classify this variability and the many exceptions to general categories mean that ecotypes are also unsuitable as is for adoption as a DU structure. However, as described above, both schemes are partially correct and have important potential as starting points for putative DUs to evaluate for their discreteness and significance.

Many caribou populations across Canada are organized into recognizable units, usually named after calving grounds for migratory populations and geographical range for others (Appendix 1). As such, they comprise natural management or recovery units (Festa-Bianchet et al. 2011). For COSEWIC (2009) to recognize such populations as stand-alone DUs, however, they must have attributes that make them discrete or evolutionary significant at a national scale and relative to neighbouring populations. Relatively little is understood about the role ofimmigration and emigration, dispersal, formation of new populations and geographic shifting of ranges. Although examples of geographic shifting have been described (Gunn et al. in press; Nagy et al. 2011), their prevalence and conditions are uncertain, albeit with some exceptions. Therefore, individual caribou populations often do not conform to the definition of designatable units (COSEWIC 2009), as they are seldom both “discrete” and “evolutionarily significant”. Nevertheless, there are some natural groupings of neighbouring populations that exhibit similarities along the same types of characteristics that underlie subspecies or ecotypic designations that can be examined for DU status. Moreover, population ranges are useful for informing DU boundaries.

We used five lines of evidence to apply the criteria for discreteness and significance as listed in the COSEWIC DU guidelines (COSEWIC 2009). Although it may have been ideal to begin the process by evaluating individual populations (i.e., bottom-up approach), a lack of data and the large number of populations over such a large ecologically diverse area prevented such an approach. Instead, we began with known groupings, such as accepted subspecies (i.e., Peary), ecotypes, or past COSEWIC-recognized units. We examined available evidence for each pre-existing group, evaluating whether or not such units were discrete and significant from other units, with a focus on neighbouring units. We also examined this evidence to determine whether any subunits merited separate DU status. In this manner, we evaluated units and their neighbours systematically, ultimately ensuring that all known geographic populations or areas with caribou in Canada were included. Following the application of these criteria, we made a qualitative decision in assessing each set of natural groupings of populations/ecotypes/subspecies relative to the full body of evidence. This decision was made in the context of the best available science as interpreted by the authors of this report, the Terrestrial Mammals Specialist Subcommittee of COSEWIC, and independent and jurisdictional reviewers.

Caribou in Canada present a major challenge for evaluating DUs because of the vast area occupied by the species, resultant behavioural differences and the relatively small amount of data available on which to base the designations. All studies that have examined these sources of variation have been limited in geographic scope, thereby making it impossible to undertake comprehensive comparisons across the entire range of the species in Canada. Most if not all relevant studies had objectives other than designating conservations units in Canada. Furthermore, these studies varied considerably in their scale of inquiry, sampling design and distribution, and adequacy of sample size.

Because some criteria for both discreteness and significance offered stronger evidence than others, DU decisions were made on multiple lines of evidence. Thus, rather than determining whether a single line of evidence met any criteria, the full body of evidence was evaluated together for the final determination for each DU.

LINES OF EVIDENCE USED TO TEST DISCRETENESS AND SIGNIFICANCE CRITERIA FOR DU STATUS

1. PHYLOGENETICS

Phylogenetic analysis of caribou has revealed two distinct groupings of genetic lineages, or clades, which suggest the isolation of caribou into at least two separate glacial refugia (Røed et al. 1991; Dueck 1998; Flagstad & Roed 2003; Cronin et al. 2005b; Eger et al. 2009; McQuade-Smith 2009; McDevitt et al. 2009). Caribou from the southern refugium comprise the North American lineage (NAL). With the retreat of the ice sheet they spread west across the boreal region, and north into the Rocky Mountains. The caribou that were isolated north of the ice sheet comprise the Beringian–Eurasian lineage (BEL). They spread south from the Beringean refugium in present-day western Yukon, north into the Arctic islands and eastwards. This distinction into northern and southern forms of caribou was recognized by biologists long before the emergence of phlyogenetics and was the basis for Banfield's (1961) taxonomy. In this manner, those of the NAL lineage are the ancestors of present day *R. t. caribou*, while BEL caribou are the ancestors of present day *R. t. groenlandicus*, *granti* and *pearyi*.

There is no evidence of monophyly within any of Banfield's subspecies. For example, Eger et al. (2009) reported that the largest proportion (38%) of the variance in the distribution of haplotypes was explained by the two lineages. This means that no subspecies corresponds to a separate clade on the phylogenetic tree. *R. t. caribou* may have been monophyletic in the past; certainly the majority of sequences from that subspecies group into a separate clade on the phylogenetic tree. However, with the retreat of the ice sheets, introgression or mixing between the two lineages occurred at zones of contact. For example, animals from the George River (Rivière George) population in Québec and Labrador have sequences characteristic of both the northern and southern lineages (Cronin et al. 2005b), as do those in the Rocky Mountains in British Columbia and Alberta (McDevitt et al. 2009) and those in northern Ontario (McQuade-Smith 2009), all classified by Banfield (1961) as *R. t. caribou*. Eger et al. (2009) remarked that "The multiplicity of haplotypes and the apparent lack of phylogeographic structuring within the caribou haplotypes supports Flagstad and Røed's (2003) suggestion that the haplotype distributions in *Rangifer* result from historical division and recolonization of the species rather than from present day relationships."

Across these studies, two separate regions of the mitochondrial genome have been used: cytochrome b (cytb; Cronin et al. 2005a, b) and control region (Flagstad & Roed 2003; Eger et al. 2009). Although this north/south divide between the lineages is evident using both marker types, that both regions have been used creates difficulties in direct comparisons countrywide, as no complete nationwide survey has been done using the same region of the mitochondrial genome.

Phylogeography is often a primary means of determining significance using COSEWIC'S DU guidelines. Apart from the NAL/BEL division, however, evidence of phlyogenetic divergence in caribou has relatively weak support, which is not surprising for a long-lived mammal. For some units, very large population sizes and unfragmented distributions mean that genetic differentiation will be slow to occur. In other cases, possible explanations for lack of evidence for divergence could include inadequate sampling or unclear assignment of samples (e.g, when collected from winter ranges where overlap between neighbouring herds could not be ruled out). This complexity made it imperative to consider phlyogenetic evidence together with as many other sources of information as possible (Paetkau 1999).

Where neighbouring DUs were sampled at the same region of the mitochondrial genome, these data were used to assess significance quantitatively. These data were also used to assess discreteness, whereby unique haplotypes were used as evidence for genetic distinctiveness. From a qualitative standpoint, because the NAL/BEL division and introgression between the two lineages in some areas were found in both regions of the mitochondrial genome sequenced, these three lineages (NAL, BEL and mixed) were used as a measure of significance, regardless of whether any neighbouring DU was sequenced at the same region of the DNA genome.

2. GENETIC DIVERSITY AND STRUCTURE

Neutral genetic markers are an increasingly common tool for monitoring wildlife populations, particularly with the emergence of many non-invasive sampling methods. Gene flow among populations may indicate areas where populations are related and exchange individuals regularly, and so should be considered together (low genetic differentiation), or areas where populations are disjunct and so should be considered as discrete from one another (high genetic differentiation).

The most common genetic statistic in the caribou literature is the genetic distance F_{ST} (e.g., Ball et al. 2010; Boulet et al. 2007; Cronin et al. 2005b; McDevitt et al. 2009). Although studies of genetic diversity and structure of caribou are available from across Canada, the differing number of loci used to assess genetic similarities, and the fact that different laboratories have carried out scoring of alleles means that quantitative comparisons among studies is not possible. Microsatellite data were compared quantitatively among DUs only where they had been surveyed in the same study and were deemed significant. F_{ST} values may vary from 0 (no difference) to 1 (completely different), however values close to 1 are exceptional, particularly for highly mobile species. Using Wright's (1978) guidelines, F_{ST} values of 0.05–0.15 indicate moderate differentiation, 0.15–0.25 great differentiation, and F_{ST} values above 0.25 revealed very great differentiation.

To account for the different sampling schemes and number of loci used across caribou genetic studies we applied a general rule whereby we accepted F_{ST} values of greater that 0.05 as indicative of significant difference between groups of caribou. However, when individuals from neighbouring DU, or neighbour areas, were sampled within the same study we accepted lower F_{ST} that were also statistically significant ($P < 0.05$). We also accepted lower F_{ST} as significantly different where individuals were assigned to separate clusters or groupings through use of a Bayesian program that did not include locations a priori. Such data were used in the support of DU only if they were further supported by at least one other discrete trait.

3. MORPHOLOGY

There is considerable morphological variation among caribou populations across their global distribution. For example, caribou possess the most morphologically elaborate and variable antlers of all members of the deer family, and the species is unique in that females have antlers (Banfield 1961; Geist 1998; Bergerud et al. 2008).

Banfield (1961) described variation in pelage and cranial measurements, which served as the basis of the most broadly accepted subspecies designations. However, the use of cranial measurements as a means to define taxonomy is problematic relative to using ratios and non-metric traits (Geist 1991; Gunn 2009). Skeletal measurements such as skull size and shape are environmentally plastic and are heavily influenced by nutrition (Couturier et al. 1989), and body size changes within populations over short temporal scales (Mahoney & Schaefer 2002; Couturier et al. 2010).

Morphological traits that have been suggested as representing local adaptations among caribou populations are: pelage, hoof shape and size, body size, antler morphology, and skull shape (Manning 1960; Banfield 1961; Gunn 2009). Detailed morphological studies have been carried out in localized areas, such as the Arctic Islands (Gunn 2009), Yukon (Kuzyk et al. 1999), and Québec (Couturier et al. 2010). However, because widespread systematic sampling of caribou morphology is lacking, these data cannot be used as a general basis for designating DUs across Canada. Hence, morphological data were compared quantitatively only when the research in question was conducted in depth by one research group and consisted of a large number of samples (excluding, for example, Banfield [1961] and Geist [1991]). Morphological data were used to evaluate discreteness only where they were also supported by at least one other discrete trait.

4. MOVEMENTS, BEHAVIOUR, AND LIFE HISTORY STRATEGIES

There is a significant volume of data on movements of caribou and such data are increasing with the application of GPS technology and satellite monitoring. Telemetry has been used to delineate population ranges and to identify calving grounds (e.g., James & Stuart-Smith 2000; Ferguson & Elkie 2004; O'Brien et al. 2006; Nagy et al. 2011). Movement data were used in this exercise, when available, to assess discreteness of putative DUs by evaluating the extent of movement between populations within and across putative DUs. Related to annual range overlap (see Distribution below), the timing of movements relative to the breeding season (rut) and thus opportunities for genetic exchange with other populations was an important consideration.

Migration and movement strategies are the distinguishing features of caribou across their range (Bergerud 2000). Movement rates in and of themselves, particularly during migration to calving/wintering grounds, can be used to distinguish between two life history strategies – dispersion and aggregation during calving. These groups are analogous to Bergerud et al.'s (2008) 'sedentary' and 'migratory' ecotypes, respectively. Differences in migration distances between these two groups can be substantial -- up to 20 times higher for migratory caribou than their sedentary counterparts. Because calving has a direct connection to individual fitness, dispersion or aggregation during calving season are assumed here to be inherited traits in response to different environments. Additional behavioural variability that relates to feeding strategy as a function of environment or ecological setting was also evident. These traits played a role in determining discreteness (inherited traits) and/or significance (evidence of local adaptations).

Caribou exhibit divergent life history strategies throughout their range, primarily related to climatic and habitat variation across latitudes and elevation. Caribou have synchronous parturition within a brief time period, which is related to body condition of females and population density (Skogland 1990) and the start of the plant growth season (Bergerud 2000). Breeding of caribou is associated with age but there also is a significant effect of body mass on reproduction in females (Cameron et al. 1993). Although variable, most life history traits overlap among subspecies and arise from a plastic response to local climatic conditions (Adams

& Dale 1998; Couturier et al. 2009) and cannot therefore be considered as evidence of local adaptation.

5. DISTRIBUTION

The distribution of animals across space and time was important for evaluating three DU criteria: 1) degree of range overlap between neighbouring populations (discreteness), 2) whether or not there is a natural disjunction between neighbouring DUs (discreteness), and 3) occurrence of the putative DU relative to eco-geographic regions (discreteness and significance).

First, annual ranges of neighbouring caribou populations are often characterized by considerable overlap and this overlap has bearing on whether they can be considered discrete. Range overlap is especially frequent during the phases of high abundance and for winter ranges (Bergerud et al. 2008). Comparisons of range overlap must, however, take into account the timing, as range overlap does not necessarily imply gene flow. Neighbouring populations can overlap on winter ranges in particularly but have little or no overlap during the breeding season (but see Boulet et al. 2007a). Importantly, degree of range overlap will vary among years and in relation to population size. While DU boundaries will ultimately represent the entire annual ranges of caribou populations, it is important that the discreteness of those ranges relative to one another be evaluated on the basis of whether or not any of the times and areas of overlap coincide with those while mating.

Natural range disjunctions that serve as barriers to movements (e.g., some bodies of water or topography) were evaluated in a similar manner to annual range overlap. Each putative DU was examined for its proximity to neighbouring units to examine whether range disjunctions were evident. As a result of human-caused landscape modification, several populations of caribou at the southern edge of the distribution are functionally isolated from other populations (e.g., Jasper, little Smokey in Alberta, southern mountain populations in British Columbia, southern Ontario, and southern Québec). This pattern of distribution is not likely to change in the near future, as it is largely an artefact of the expansion of the human footprint over the past 150 years. We distinguished natural from artificial range disjunctions in evaluating discreteness.

Finally, if the DU occupied a unique eco-geographical region relative to other DUs, this distribution was used as supporting evidence for its discreteness. When considered in conjunction with local adaptations, this evidence also suggested evolutionary significance.

CARIBOU DESIGNATABLE UNITS

Below are descriptions of 12 designatable units for caribou in Canada (Figure 4). Although more putative DUs were evaluated for their discreteness and significance, only the final set appear in this report. In each section, available information for all lines of evidence is summarized, and this is followed by a discussion of how these data have collectively resulted in meeting the COSEWIC DU criteria for both discreteness and significance. For most DUs, there remain uncertainties that will require resolution before status determinations are made by COSEWIC. These are primarily related to the recognition of additional potential DUs, and uncertainties in the definition of boundaries and the assignment of some populations to the most appropriate DU. Summary tables comparing the basis and strength of evidence across all 12 DUs appear at the end of the section.

DU1: PEARY CARIBOU

Peary caribou were recognized as a distinct subspecies (*R. t. pearyi*) by Banfield (1961), a classification that is broadly accepted for caribou belonging to this DU. They are the only caribou occupying the upper islands of the Canadian Arctic including the Queen Elizabeth Islands, Prince of Wales Island, Banks Island, Somerset Island, northwest Victoria Island and several smaller islands across the archipelago. A population of Peary caribou is known to calve on the very northern extension of the mainland on Boothia Peninsula. In its 1991 COSEWIC assessment, Peary caribou and Dolphin and Union caribou were recognized as three separate 'populations'. In 2004, however, the Dolphin and Union population was assessed as a separate unit while the remaining caribou were combined back into one unit (Peary) (COSEWIC 2004).

LINES OF EVIDENCE:

PHYLOGENETICS

Analyses of mtDNA suggest that Peary caribou evolved relatively recently (within the last 10,000 yrs) and do not represent a monophyletic lineage (Eger et al. 2009). They have a similar phylogenetic lineage to European wild reindeer (*R. t. tarandus)*, suggesting a common refugium for the two subspecies north of the ice sheets in Beringia (Flagstad & Røed 2003). Peary caribou share haplotypes with *R.t. groenlandicus* and *R. t. caribou* (Flagstad & Røed 2003), which may indicate either rare long-distance migrations between ranges or incomplete lineage sorting. Eger et al. (2009) sampled caribou from 16 locations, including within the distribution of Peary caribou and neighbouring mainland populations, and sequenced the control region of mitochondrial DNA (mtDNA). They found high haplotype diversity in Peary caribou, although a single haplotype, 65, was dominant across the islands.

The most widespread phylogeographic analyses of *Rangifer* using cytochrome b (cytb) mtDNA (Cronin et al. 2005a, b) was augmented by (McQuade-Smith 2009) with data from Peary individuals on Ellesmere Island. A phylogenetic tree produced using McQuade-Smith's (2009) data was similar to that of the control region data (Finnegan et al. unpublished data). The only division on the phylogenetic tree is between the BEL (*R. t. groenlandicus, granti, and pearyi*) and NAL (*R. t. caribou*). Therefore, phylogenetic analysis completed to date does not separate this DU from neighbouring units.

GENETIC DIVERSITY AND STRUCTURE

Genetic structure analysis of mitochondrial DNA by Eger et al. (2009) found no relationship between subspecies designation and control region mtDNA differentiation; between-subspecies differences explained only 7.62% of the variation within the data set. McQuade-Smith (2009) reported a similar lack of differentiation among sampled areas across Canada, again supporting the lack of congruence between phylogenies and described subspecies.

Zittlau et al. (2004; 2009a) amplified DNA at eight microsatellite markers and investigated the relationship among caribou from the Arctic Islands, Boothia Peninsula and four caribou populations from the mainland. They found that caribou sampled on the Arctic Islands were more genetically differentiated from those on the mainland than from one another (Inter island F_{ST} 0.005-0.11, Island v mainland F_{ST} 0.011-0.22), although there was more genetic differentiation among Peary populations than among mainland populations. Despite being located on the same island, the Victoria Island Peary caribou and Dolphin and Union populations were differentiated from one another (F_{ST} 0.200). The caribou of the Boothia Peninsula and Banks Island showed little differentiation from Peary caribou with low F_{ST} values (0.018) and close proximity on the neighbour joining tree (Zittlau et al. 2009b).

Zittlau (2004; 2009a) reported significant levels of microsatellite differentiation among some islands, particularly between the caribou of Melville Island and the Bathurst complex (F_{ST} 0.005). Accordingly, the authors suggested that there are five distinct genetic populations on the Arctic Islands: 1) Western Queen Elizabeth Islands, 2) Prince of Wales-Somerset, 3) Boothia Peninsula, 4) Banks and northwestern Victoria Island, and 5) Dolphin and Union population, although they acknowledged the lack of samples from the northeastern islands including Devon and Ellesmere.

Røed et al. (1986) reported four transferrin alleles unique to Peary caribou samples, providing further support to the microsatellite data, which has revealed genetic distinction of Peary caribou from other subspecies at nuclear markers. Røed et al. (1986) found unique transferrin alleles on Somerset Island and the Boothia Peninsula but the majority of the alleles were reported on more than one island.

Within Peary caribou, Peterson (2008) investigated genetic structure on northern Ellesmere Island using both microsatellite markers and mtDNA. He found no evidence of population substructure using microsatellite data (K=1, Structure analysis) and there were significant, but low genetic distances among sampling localities on Ellesmere Island using both these data (F_{ST} 0.013-0.11, $P < 0.028$ in all cases) and haplotype data ($F_{ST} = 0.298\text{-}0.550$, $P < 0.05$ in all cases).

MORPHOLOGY

Manning (1960) and Banfield (1961) described Peary caribou (*R. t. pearyi*) as distinct from *R. t. groendlandicus* and *R. t. granti* because of their densely-haired whiter pelage, smaller size, shorter faces (caused by significantly distinct ratios of skull bones), larger hooves and more narrowly spreading antlers. Thomas and Everson (1982) examined body, leg bone, and skull and pelage data from the Boothia Peninsula northwards to the Queen Elizabeth Islands. Although patterns did emerge, with the Queen Elizabeth Islands animals distinct from those on the islands further to the south, these followed a cline, similar to that described by Manning (1960). Gunn (2009) reported that pelage and antler velvet showed a discontinuous distribution, rather than a cline, between mainland and Peary caribou. These suggest Peary caribou are distinguishable from Barren-ground caribou (DU3) and Dolphin and Union caribou (DU2) morphologically, and that there is no clear morphological differentiation within Peary caribou to support any subdivision.

MOVEMENTS AND BEHAVIOUR

Peary caribou population ranges are defined by island or island complex boundaries that are connected by sea ice for most of the year. Individuals use islands in close proximity to one another to meet life requirements, often migrating between islands (Miller 1990). During severe winters, Peary caribou occasionally make long distant movements to the mainland ("desperation movements" in Miller 1990). Calving sites and rutting areas are distinct from both the Dolphin and Union population (DU2) and Barren-ground populations (DU3) (Species at Risk Committee 2011; Nishi 2000).

The current distribution is naturally discontinuous due to island geography. DNA analyses indicate lack of recent gene flow (McFarlane 2009), and steep declines in some populations have resulted in the cessation of movement between some islands (Species at Risk Committee 2011.). Jenkins et al. (2011) recognized five "island group" Peary caribou populations based on seasonal distribution and data derived from radio-telemetry and observations of seasonal inter-island movements .

Peary caribou are mostly dispersed in small groups and do not display the large aggregations of mainland caribou (DU 3) either during calving or post-calving (Miller et al. 1977). They display a continuum from use of relatively small year-round home ranges to seasonal migrations between seasonal ranges. Those seasonal migrations often include crossing the sea-ice between islands (Miller & Gunn 1978; Miller 1990; Miller 2002; Jenkins et al. 2011).

DISTRIBUTION

The range of Peary caribou is restricted almost entirely to the Arctic Islands (except Baffin Island) and the Boothia Peninsula. Rarely, during severe winters, and at the individual scale, Peary caribou distribution may sporadically overlap with that of Barren-ground caribou (DU3). There is some potential overlap with the Dolphin and Union caribou (DU2) of Victoria Island.

DISCRETENESS AND SIGNIFICANCE

The discreteness of the Peary caribou DU is based on genetics, morphology, and behaviour. Measures of genetic divergence among Peary caribou and those on the mainland, and also between them and the Dolphin and Union caribou support the discrete nature of Peary caribou from both adjacent DUs (DU2 and DU3), even in the presence of occasional overlap in annual distribution. The unique behaviour of Peary caribou, using numerous islands as part of their home range, marks them as discrete from Barren-ground caribou (DU3). The grey antler velvet, breeding and seasonal pelage colors and relative proportion of skulls, legs and hooves are all morphological attributes that further support the discreteness of members of this DU.

Although Peary caribou have unique haplotypes, there is no evidence of monophyly of the subspecies. The distinct differences between Peary caribou and other members of *Rangifer* is likely a product of recent evolution (within the past 10,000 yrs) and intense selection pressures within an unpredictable and severe environment (Eger et al. 2009; Gunn 2009). It is likely that the discrete inter-island movement patterns of these caribou reflect local adaptations, as they are not found elsewhere within caribou range and therefore represent a significant trait. Additionally, the occurrence of Peary caribou as far north as Ellesmere island, and the considerable declines in Peary caribou populations (with no replacement of the area with caribou from further south) across the Archipelago (Miller & Gunn 2003; Gunn et al. 2007; Miller et al. 2007b; Vors & Boyce 2009) suggest that Peary caribou have local adaptations that are not present elsewhere in the range of the species. Had such adaptations been present in the caribou found further south, there may have been the possibility of augmentation or rescue of declining Peary caribou populations (Gunn et al. 2011; Species at Risk Committee 2011.), particularly those found on the southernmost Arctic Islands (Dolphin and Union caribou; DU2).

Although both genetic and movement data suggest heterogeneity within Peary caribou (see Jenkins et al. 2011), levels of genetic divergence among the reported populations are relatively low. The latter may suggest population interchange, but available evidence indicates it is more likely that such patterns are reflective of inadequate sampling across the vast range and/or lack of adequate time for divergence. Morphological data, however, suggest that various characteristics are distributed in clinal fashion, and provide little evidence of discrete morphological divisions (Gunn 2009). There is no evidence pointing to any Peary caribou populations being evolutionarily significant units that would merit separate DU status. Ongoing microsatellite DNA studies using material from a broader geographic distribution and more loci will provide new information on variation within and between island groups of Peary caribou (Jenkins et al. 2011).

DU2: DOLPHIN AND UNION CARIBOU

Dolphin and Union caribou belong to one population of caribou that migrate across the sea ice in the Dolphin and Union Strait between Victoria Island and the central Canadian Arctic mainland. This group has had a particularly confused taxonomic history (COSEWIC 2004). First singled out for their uniqueness by (Manning 1960), Dolphin and Union caribou have been alternatively classified as *R. t. groenlandicus, R. t. pearyi* and *R. t. groenlandicus × pearyi.* In recognition of their uniqueness relative to neighbouring Peary caribou (DU1) or mainland Barren-ground (DU3), recent authors have increasingly referred to them as *R. t. groenlandicus × pearyi* , pending formal reclassification of *Rangifer* (Poole et al. 2010; Nagy et al. 2011; USFWS 2011). Dolphin and Union caribou were first assessed by COSEWIC as part of Peary caribou, but the latest assessment considered the Dolphin and Union group separately (COSEWIC 2004).

LINES OF EVIDENCE:

PHYLOGENETICS

Dolphin and Union caribou are from the BEL lineage and share one of five haplotypes with the Bluenose population of Barren-ground caribou (DU3; Eger et al. 2009). There is no evidence of monophyly in Dolphin and Union caribou (Cronin et al. 2005b).

GENETIC DIVERSITY AND STRUCTURE

Genetic analyses have revealed that the Dolphin and Union caribou have more similarity to the caribou of the mainland (DU3) than to Peary caribou (DU1), including those residing on northwest Victoria Island. Zittlau et al. (2009a) examined caribou from Boothia Peninsula, Dolphin and Union, and mainland populations for genetic distinctness. The Dolphin and Union population was the most genetically distinct, with 87% of the individuals self-assigned to the population from which they were sampled. They were genetically more similar to the mainland populations than to the Peary caribou that occur on the same Arctic Island. However Dolphin and Union caribou were differentiated from Barren-ground (DU3) and Peary caribou (DU1)and were distinct based on allele frequency and high F_{ST} (Ds) values (Zittlau 2004; Zittlau et al. 2009).

MORPHOLOGY

Dolphin and Union caribou are best described as intermediate in body size between the Peary caribou of the Arctic Islands further north and the migratory populations of mainland Canada but they are distinctive in appearance. They are generally larger than Peary caribou, but have the characteristic proportions (shorter head and legs), and are significantly smaller and lighter in colour than members from the mainland populations (Manning, 1960). The quantitative data on these morphological differences, indicate that morphology can be used as a line of evidence to assign this DU. Their skull shape, antler velvet colour and hoof size are similar to Peary caribou and distinctive from Barren-ground caribou (DU3; Gunn & Fournier 1996; Manning 1960). Breeding pelage is distinct from both Peary (DU1) and Barren-ground caribou (Gunn & Fournier 1996).

MOVEMENTS AND BEHAVIOUR

Dolphin and Union caribou make directional movements in the fall and early winter southward on Victoria Island, staging and rutting along the southern coast while waiting for the sea ice to form, after which they migrate across the Dolphin and Union Strait to the central Canadian Arctic mainland. In late winter-spring they return across the sea ice before break-up, and remain on Victoria Island for calving and post-calving before returning again to their mainland winter range (Nagy et al. 2009; Poole et al. 2010). Satellite telemetry has revealed that Dolphin and Union caribou comprise one population that is geographically or temporally isolated from other caribou during calving and the rut (Nagy et al. 2011; Poole et al. 2010). Dolphin and Union caribou have a dispersed calving strategy (Nishi 2000).

DISTRIBUTION

The annual range of the Dolphin and Union population has some possible overlap with that of the Peary caribou on Victoria Island (DU1). During winter, overlap occurs in some years with the Bathurst and Ahiak Barren-ground populations (DU3) on the mainland. The various groups seldom occupy these overlap areas at the same time of year, and not during calving or the rut. Similar to Peary Caribou (DU1), Dolphin and Union caribou are restricted to the Arctic ecoregion.

DISCRETENESS AND SIGNIFICANCE

Dolphin and Union caribou are discrete from Peary caribou (DU1) based on microsatellite differentiation and are discrete behaviourally and morphologically from Barren-ground caribou (DU3). They are structured as a discrete population relative to neighbouring caribou, and are geographically or temporally isolated from most other caribou throughout the year, including on Victoria Island, where calving and rutting take place (Nagy et al. 2011, Poole et al. 2010). As a result, limited or no gene flow occurs between them and neighbouring caribou populations despite some distributional overlap.

While Dolphin and Union caribou share haplotypes with members of adjacent DUs, the retention of some distinct genetic lineages suggests possible local adaptations by these caribou. Their physical similarity to Peary caribou (DU1) may reflect similar evolutionary selection pressures, but genetic information suggests a different origin. The uniqueness of this population also reflect a severe population bottleneck that occurred in the early 1900s (Manning 1960; Zittlau 2004; Zittlau et al. 2009a). Dolphin and Union caribou are significantly different from Barren-ground caribou (DU3) because their regular twice-annual migratory pattern across sea ice is unique and reflects the unique ecological setting. The scale of this migration (thousands of individuals) is also distinct from the often dispersed individual-scale sea ice movements of Peary caribou. Dolphin and Union caribou are also easily recognizable because of distinctive morphological attributes that include skull shape, antler velvet colour, hoof size, and breeding pelage pattern (Gunn & Fournier 1996; Manning 1960) and they are visibly smaller than mainland caribou. The fact that this differentiation occurs in the face of annual range overlap with other caribou implies local adaptations and is therefore considered to be evolutionarily significant.

DU3: BARREN-GROUND CARIBOU

Populations in this DU are residents of the continental subarctic tundra, which in Canada ranges across the Mackenzie Delta to the eastern coast of mainland Nunavut, and south into northern Saskatchewan and Manitoba. This DU includes caribou of Baffin Island and the Hudson Bay islands of Southampton, and Coats. The range of the Porcupine and Forty-Mile caribou populations extend into Alaska. All populations were classified as belonging to the barren-ground subspecies (*R .t. groendlandicus*) by Banfield, except the Porcupine and Forty-Mile populations , which he classified as *R.t. granti* “intergrades” with features resembling *R. t. groenlandicus* (pure *granti* were from the Alaskan Peninsula). Populations in this DU have never been assessed by COSEWIC.

LINES OF EVIDENCE:

PHYLOGENETICS

Caribou belonging to this DU are predominantly of the BEL lineage. Research has found some NAL haplotypes in Barren-ground populations, notably those that occur in the southern extent of this DU (Dueck 1998). Cronin et al. (2005b) found a shared haplotype between the Baffin Island and George River population (woodland caribou subspecies) in Québec/Labrador. Previous studies show no evidence of monophyly of either *R. t. groendlandicus* or *R. t. granti*, and recent mtDNA analyses confirm no phylogenetic distinction that would support identifying these as two different subspecies (Weckworth et al. 2011).

There are no clear phylogenetic groupings between populations belonging to this putative DU. Analysis of both cytb and the control region of the mitochondrial genome revealed considerable sharing of haplotypes among all populations (Flagstad & Røed 2003; Cronin et al. 2005b). Cronin et al. (2005b) identified five haplotypes in the Baffin Island and Bluenose Barren-ground populations, two of which were found in both populations, and one of these two was also found in the Central Arctic population of Grant’s caribou (in Alaska). McQuade-Smith (2009) identified 26 haplotypes. Among populations sampled by Cronin et al. (2005b), a single haplotype was prevalent (also found in Peary caribou). Dueck (1998) reported no monophyly in distinct populations with phylogenetic clades including a mixture of individuals from Baffin and Bathurst individuals, and Baffin, Bathurst and Bluenose caribou. A shared haplotype was found between Baffin Island caribou and reindeer from Eurasia. As >600 reindeer were brought from

Norway to southern Baffin Island in 1921, it is possible that introgression took place between the caribou of Baffin Island and the introduced reindeer. Baffin Island caribou also shared haplotypes with the Dolphin and Union and Bluenose populations (Cronin et al. 2005b).

Mitochondrial DNA clades generally support the separation of Barren-ground caribou from populations that represent the southern mitochondrial clade, which includes those belonging to DUs 4, 5, 6, 9, 10, and 11 (Weckworth et al. 2011; McDevitt et al. 2009; Eger et al. 2009; Zittlau et al. 2009a; Cronin 2005a,b). Although members of DU3 appear to be of a similar lineage to Northern Mountain caribou (DU7), there is some evidence of more recent divergence between these two groups (Weckworth et al. 2011; Eger et al. 2009). Phylogenetic analyses have, however, failed to separate R. t. groenlandicus and R. t. granti and Grant's caribou from Peary caribou and Dolphin and Union caribou (DU1 and 2) (Weckworth et al. 2011; Eger et al. 2009; Zittlau 2004; Zittlau et al. 2009b).

GENETIC DIVERSITY AND STRUCTURE

Cronin et al. (2005b) sampled caribou belonging to Banfield's (1961) barren-ground, Grant's and woodland caribou subspecies. Cronin et al. (2005b) found less genetic differentiation within subspecies than among them. Using mitochondrial data, F_{ST} values between Grant's caribou and Barren-ground were 0.097 to 0.167, those between Grant's and woodland subspecies were 0.147 to 0.355, and those between barren-ground and woodland subspecies 0.195 to 0.518. Microsatellite analyses were similar to the mitochondrial analyses. F_{ST} values between *R. t. groenlandicus* and *R. t. granti* were 0.045 to 0.087, between barren-ground and woodland subspecies were 0.076 to 0.332, and between Grant's and woodland subspecies were 0.021 to 0.219.

Cronin et al. (2005b) reported small mitochondrial and microsatellite DNA genetic distances among several Alaskan populations of Grant's caribou (mtDNA F_{ST} 0.002-0.037; Microsatellite F_{ST} 0.002-0.032) and among the barren-ground caribou of south Baffin Island and the Bluenose population of the Northwest Territories (MtDNA F_{ST} 0.049; Microsatellite F_{ST} 0.089). In contrast, differentiation between populations belonging to barren-ground and woodland subspecies (MtDNA F_{ST} 0.195-0.518; Microsatellite FST 0.076-0.346) and among populations of Grant's and woodland subspecies(MtDNA F_{ST} 0.147-0.240; Microsatellite F_{ST} 0.021-0.219) was more pronounced.

Zittlau et al. (2009b) compared microsatellite DNA diversity among populations of barren-ground (Cape Bathurst, Bluenose West and East, Bathurst, Ahiak, Beverly and Qamanirjuaq) and the Porcupine caribou population (from the Grant's subspecies). Genetic distances (DS) ranged from 0.059 to 0.168. The Porcupine population was the most highly differentiated from the other populations sampled (0.124 to 0.168). Genetic differentiation among Barren-ground and Grant's caribou was low, while that among populations of those subspecies and woodland caribou subspecies were generally higher. There is no known significant differentiation among populations within the two subspecies, although recent genetic analyses have suggested that some genetic structure may exist within this DU (McFarlane et al. 2011).

No genetic survey has included caribou from Coats Island, but McFarlane et al. (2011) did include samples from Southampton Island for the first time, finding them to be very distinct from mainland caribou, and from Dolphin and Union caribou. Preliminary results from microsatellite DNA studies involving Baffin Island caribou samples suggest these populations are discrete from other barren-ground populations in this DU (D. Jenkins, pers. comm. 2011).

MORPHOLOGY

No comprehensive morphological survey of caribou subspecies or variation within the Grant's and barren-ground subspecies has been carried out since Banfield (1961).

MOVEMENTS AND BEHAVIOUR

Caribou populations belonging to this DU have been traditionally defined based on the location of calving grounds (Russell et al. 2000), although Nagy et al. (2011) have documented use of more than one calving range by individual caribou that may occur under particular conditions such as low densities (Gunn et al. in press). The seasonal range of populations may overlap (Gunn et al. 2001), although they are typically geographically separate during calving, post-calving and rut (Russell et al. 2000; Gunn et al. 2011). Neither population range nor the location of calving grounds is geographically stationary (e.g., Ferguson & Messier 2000; Ferguson & Gauthier 2001; Gunn et al. in press; Nagy et al. 2005; Nagy et al. 2011). Movements of individuals between Bluenose East and neighbouring populations are apparently rare (Patterson et al. 2004). In a long-term study of the George River and Leaf River herds, Boulet et al. (2007) showed that 9% of females switched to another calving ground at least once in their lifetime in northern Québec and Labrador.

There are no recorded movements of caribou from Baffin Island, Coats or Southampton islands to the mainland (Jenkins & Goorts 2011).

Most caribou in this DU aggregate during calving and undertake long-distance migrations between the boreal forest region or the tundra in the winter, and calving areas on the tundra. Barren-ground caribou are highly gregarious, although the scale of both migrations and aggregations vary over time and among populations. Post-calving aggregations often involve tens of thousands of individuals. The distance to the treeline relative to calving grounds increases markedly in Nunavut, such that individuals from populations in the eastern part of this DU remain on tundra during winter (tundra-wintering herds; Nagy et al. 2011). Population size is another factor that may influence whether or not individuals reach the boreal forest habitat in winter, because the annual range tends to contract when a population is at low numbers.

The caribou of north Baffin Island have been described as having a different behaviour, with calving being dispersed rather than aggregated (Jenkins & Goorts 2011), which may reflect local adaptations. However, the three Baffin Island populations exhibit variability in this regard, and may exhibit a dispersed calving strategy as a consequence of recent population depletions. Preliminary data suggest that the caribou on northern Baffin Island do not undergo large-scale migrations to calving grounds, but instead use a portion of their winter range for calving. Recent radio-collaring efforts have found caribou dispersing alone into high, rocky areas to calve (D. Jenkins, pers. comm. 2011).

DISTRIBUTION

The total range of the caribou populations belonging to this DU overlaps with that of Peary caribou (DU1) and Dolphin and Union caribou (DU2) on the Boothia Peninsula and on Victoria Island, with some populations of Northern Mountain (DU7) in Yukon and NWT, and Boreal (DU6) in Manitoba, Saskatchewan, and Alberta. For the most part, however, populations do not overlap during rutting in the fall, the period when genetic exchange is most likely to occur. Populations on South Coats and Baffin Islands do not overlap with other populations.

Caribou in this DU are found in the Arctic, Boreal, and Northern Mountain ecoregions. They share ecoregions with the Peary caribou of the Arctic Islands (DU1) and the Boreal caribou (DU6) of the south.

DISCRETENESS AND SIGNIFICANCE

The Barren-ground DU is a discrete and significant unit due to the combination of phylogenetic lineage and adaptive behaviours. The former distinguishes this DU from Eastern Migratory caribou (DU4) of Québec/Labrador and Ontario/Manitoba that exhibit similar aggregating calving behaviour, while the latter distinguishes them from the Peary (DU1) and Dolphin and Union (DU2) caribou of the far north. The combination of two subspecies (*R. t. groenlandicus*, *R. t. granti*), which Banfield (1961) distinguished on the basis of morphology (albeit with considerable overlap) into a single DU can be justified on the basis of their genetic and behavioural similarity. Although members of DU3 and DU6 each possess unique haplotypes, they also share common haplotypes. Measures of genetic divergence between them are relatively high, and an order of magnitude higher than that between caribou Banfield (1961) assigned to *groenlandicus* and *granti* subspecies. The populations of Baffin Island, Southampton and Coats are discrete as they are isolated from other Barren-ground populations by natural range disjunction.

Phlyogenetically, *R. t. groenlandicus* and *R. t. granti* do not greatly differ genetically from other caribou. This pattern may reflect the relatively short time since initial colonization of the region after glaciation and effective population size, which is so large that it reduces genetic drift (McFarlane et al. 2011). They are of the BEL lineage, similar to Peary caribou (DU1) and share haplotypes with individuals of that subspecies and those of the Eastern migratory caribou (DU4) in northern Québec/Labrador. Their adaptive behaviour, such as aggregated calving marks them as distinct from caribou of the NAL lineage (DU5, 6, 9, 10, and 11) and from those that share the BEL lineage (Peary [DU1], Dolphin and Union [DU2], and Northern and Central Mountain populations [DU 7,8]). They have similar behaviour to the caribou of Québec/Labrador (DU4) but do not share the BEL lineage with those caribou. Members of DU3 are the only caribou that occupy both the Arctic and Boreal ecoregions.

UNCERTAINTIES TO BE RESOLVED

The isolation of the three Baffin Island populations from other members of this DU suggests discreteness. However, no phylogenetic difference was apparent from the cytochrome b gene, which may result from human interference as previously mentioned, or may reflect a very recent separation. Insufficient study has been undertaken to determine whether variability of movements and behavioural ecology among the three populations are different from all other populations within this DU. Results from ongoing radio-telemetry and genetic studies and collections of ATK will help inform whether members of Baffin Island warrant separate DU status from DU3.

The caribou of Coats Island and Southampton Island occupy a disjunct range from the mainland populations, suggesting that they too are discrete from other populations within this DU. Caribou on Southampton Island became extinct in the 1960s, supporting the fact that the range disjunction of this population likely prevents natural re-colonisation. The current Southampton Island population was reintroduced from Coats Island (Ouellet et al. 1993). Therefore, the Coats Island and Southampton Island caribou population may have occupied a disjunct range from other caribou for a sufficient amount of time for local adaptations to manifest, and may occupy a range that prevents natural re-colonization of those islands. Further effort is necessary to evaluate the relationships between these caribou and those from other populations within DU3, DU4, and Baffin Island. In addition, the south-western boundary of this DU requires resolution with respect to overlap with Northern Mountain populations (DU7), and particularly the assignment of the Forty-Mile population.

DU4: EASTERN MIGRATORY CARIBOU

This DU includes at least three populations (George River, Leaf River, and Pen Island populations) and possibly a fourth (Cape Churchill) that occur in open-tundra and boreal habitats of northern Labrador, Québec, Ontario and Manitoba. Although this northern form was recognized as a distinct subspecies (*R. t. caboti*) by early mammalogists (see Bergerud et al. 2008), Banfield (1961) assigned it to the woodland caribou subspecies (*R. t. caribou*) based on skull measurements. Populations in this DU have never been assessed by COSEWIC.

LINES OF EVIDENCE:

PHYLOGENETICS

The aggregated calving caribou of northern Québec and Labrador and northern Ontario and Manitoba are predominantly of the NAL lineage. Hence, phlylogenetic data analysed independently in a number of studies have lent support to Banfield's (1961) original assignment of these populations into the larger group of caribou that colonized Canada from south of the ice sheets following the glaciers' retreat (McDevitt et al. 2009; Eger et al. 2009). Phylogenetic analyses by Eger et al. (2009) indicated that caribou from Ontario, northern Quebec, and

Newfoundland are closely allied and notably distinct from northern populations. There are, however, some shared haplotypes with *R. t. groenlandicus* and *R. t. granti* of northwest Canada (DU3; Cronin et al. 2005b). Preliminary work in Ontario also found introgression of northern BEL lineages into the aggregated calving populations (McQuade-Smith 2009). BEL lineages have been reported in other populations of caribou that are primarily of NAL lineage, such as the montane caribou of Alberta and British Columbia, which likely indicates post-glaciation hybridization (McDevitt et al. 2009). Cronin et al. (2005b) reported no shared haplotypes among the George River population and the populations of Newfoundland, or between the George River population and the Val d'Or population of southern Québec. Flagstad and Røed (2003) found a shared haplotype between the George River population of northern Québec and Svalbard, Norway. There has been no phylogeographic study including both the aggregated calving populations of Ontario/Manitoba and Québec/Labrador, and no samples from the western-most portion of this DU (Cape Churchill population) have been compared with those of neighbouring populations.

GENETIC DIVERSITY AND STRUCTURE

Cronin *et al*. (2005b) sampled the George River population in Québec and Labrador in their comparisons across Canada. Measures of genetic distance using microsatellite DNA were lower between that population and four Alaskan and Yukon populations of Grant's caribou (F_{ST} 0.147 to 0.199) than between the George River caribou and Val d'Or populations in boreal Québec (F_{ST} 0.365). Differentiation was also high between the George River population and caribou from Alberta (F_{ST}=0.544). Similarly, higher genetic differentiation was detected between the George River population and other boreal caribou populations using microsatellite DNA (Cronin *et al*. 2005b). Courtois *et al*. (2003a) investigated genetic DNA structure at eight loci in seven populations in south and central Québec and concluded that all sampled populations exhibited significant genetic differentiation, particularly between DU4 and DU11 (Gaspésie) populations. They reported F_{ST} values ranging from 0.087 to 0.172 between caribou belonging to this DU and those from DU6 (Boreal) and DU 11 (Torngat samples were not included). Later work by Boulet *et al*. (2007) in central and northern Québec used seven loci (also genotyped by Courtois *et al*. 2003a) to study seven other populations (two migratory, one montane and four sedentary [boreal] populations). They found significant but low differentiation between the DU4 populations and those from DU6 (Boreal) further south in Québec (F_{ST} values of 0.017 to 0.038) and little differentiation between the two migratory George River and Leaf River herds, and the Torngat montane herd, although the latter had a low number of samples.

In Ontario, preliminary genetic work (McQuade-Smith 2009) reported little genetic differentiation between the aggregated calving Pen Island population (DU4) and Boreal caribou (DU6) (F_{ST} approximately 0.020-0.030; Table 2). No study has included comparisons between the Ontario/Manitoba caribou and the Québec/Labrador caribou; additionally, the Cape Churchill herd remains unsampled.

MORPHOLOGY

A detailed morphological assessment of the caribou in northern Québec and Labrador was completed by Couturier *et al*. (2010). Hind foot length, girth, and body length differed significantly between George River and Leaf River caribou that aggregate at calving and sedentary boreal populations in Labrador (Red Wine, Jamésie, Mealy mountains and Lac Joseph), and between these two groups of caribou (George River/Leaf River and Boreal caribou) and the montane caribou (Torngat Mountains). There were also differences among the populations within the ecotypes. Bergerud (1967) found differences in jaw length between the George River animals and those from the boreal population in the Mealy Mountains. Bergerud *et al*. (2008) detailed notable differences in antler morphology between sedentary boreal and migratory populations in Québec/Labrador. Couturier *et al*. (2010) evaluated body condition and reported differences between the George River and Leaf River populations. However, these differences were not constant across years and were related to population density rather than to any morphological distinction. Banfield (1961) remarked on the distinctiveness of George River animals for the common absence of the rear antler tine among other differences between sedentary and migratory caribou (summarized in Bergerud *et al*. 2008).

No morphological analysis of the caribou within the Ontario/Manitoba portion of this DU and between the Québec/Labrador and Ontario/Manitoba populations of caribou has been done.

MOVEMENTS AND BEHAVIOUR

The Pen Island and Cape Churchill populations of northern Ontario and Manitoba undertake seasonal movements south to the boreal forest in the winter and north to the Hudson Bay coast in summer where they form aggregated populations at calving (Abraham & Thompson 1998; Abraham et al. in press). The George River and Leaf River caribou move between the north of Québec and Labrador south to the boreal forest of Québec in winter. Although calving grounds are separate, some interchange between these populations has been recorded (Boulet et al. 2007; Couturier et al. 2009). Members of the Leaf River (Rivière aux Feuilles) population intermingle with the Jamésie population in the Boreal DU (DU6) farther south during winter, although not in every year. The same is true for the George River population, which sometimes shares a wintering range with the boreal Red Wine Mountains population, the northern extent of the Lac Joseph winter range, and on rare occasions, the Mealy Mountains population (Schmelzer et al. 2004). There is no overlap during rut between members of these populations, and no documented cases of calving site switching between migratory and boreal populations (I. Schmelzer, pers. comm., 2011). Within the southern portion of the Torngat Mountain (DU10) caribou range, there is some intermingling between George River animals during spring migration and post-calving periods. Overlap can occur during the rut, but rarely (Schaefer & Luttich 1998; Boulet et al. 2007; S. Luttich, in litt.).

Some radio-collared individuals from the neighbouring Qamanirjuaq population (from DU3) have occasionally travelled to the Cape Churchill range (M. Campbell, pers. comm.). Although most have returned fairly quickly, at least one remained during the calving, post-calving and into the rutting stage one year before returning. Calving grounds of the two populations are quite separate from one another (M. Campbell, pers. comm. 2011). Although James Bay does routinely freeze over, there have been no recorded movements between the two populations of Québec and Labrador and those of Ontario and Manitoba (OMNR, unpublished data, S. Couturier, unpublished data), which are separated by just over 200 km. Likewise, movements of members of this DU from Québec into or across the Hudson Bay and across islands such as Mansell, Coats, and Southampton have not been recorded, although some possible northern routes of exchange have been identified (S. Couturier, pers. comm. 2011).

All populations in this DU display aggregated calving behaviour similar to the large Barren-ground populations of northern Canada (DU3). The number of animals in these populations tend to cycle with observed lows of approximately 5000 animals in the George River population in the 1950s (Banfield & Tener 1958) to high densities of 775,000 animals in the 1980s (Williams & Heard 1986; Couturier et al. 1996; Bergerud et al. 2008). Individuals travel very long distances (>1000 km at times) to calving grounds and other summer habitats (Couturier et al. 1988, 1989 & 1990; Messier et al. 1988; Crête & Huot 1993). Although calving grounds are not geographically fixed over time on a local scale, they have been located in the same region for centuries (Couturier 2007). The movements of aggregated calving caribou in Ontario/Manitoba are more geographically restricted. The Pen Island range has recently shifted from the traditional calving grounds of Pen Island east to Cape Henrietta Maria (Magoun et al. 2005; Abraham et al. in press).

DISTRIBUTION

With Hudson Bay acting as an important barrier, there is no known overlap in the annual ranges of George River, Leaf River, and Pen Island populations and caribou from DU3. The annual ranges of the two populations in Québec and Labrador overlap with one other and with those of Boreal (DU6) and Torngat (DU10) DUs to the south and east as described above. The annual ranges of the Pen Islands and Cape Churchill populations of Ontario and Manitoba likewise overlap with Boreal caribou (DU6) to the south. However, these overlaps are all partial when viewed seasonally, as they occur during winter only, when there is little chance for genetic interchange. Rutting and calving ranges of populations of this DU are separated from those of neighbouring DUs by long distances, with the exception of George River and the southern Torngats. There is some distributional overlap between the Qamanirjuaq and Cape Churchill populations on the western end of this DU, most of which occurs during winter. More study is required to resolve the origin and classification of the Cape Churchill population (Bergerud et al. 2008).

The two populations of Québec and Labrador are found in the Arctic and Boreal Ecoregions, while those of Ontario and Manitoba are found in the Boreal Ecoregion only. The latter contains a coastal band of the southernmost zone of continuous tundra vegetation and continuous permafrost in North America in the Hudson Plains Ecozone (OMNR and ESTR Secretariat 2011).

DISCRETENESS AND SIGNIFICANCE

Although the populations in this DU are of a similar ecotype (migratory-tundra caribou with aggregated calving behaviour) to those belonging to the Barren-ground DU (DU3), they are discrete from the latter by virtue of natural disjunction (Hudson Bay) for most of the range. There is more ambiguity regarding discreteness along the western portion of this DU where there is a zone of overlap. Although both Pen Islands and Cape Churchill populations have received little study relative to the George and Leaf River populations (OMNR and ESTR Secretariat 2011), they are assumed to be discrete units with few opportunities for genetic exchange with their neighbours. The four populations within DU4 are discrete from the Boreal (DU6) caribou to the south and the Torngat population (DU10) to the east, with which they share some portion of their annual ranges, but differ in their behaviour (aggregated calving vs. dispersed calving) and ecology (boreal-tundra vs. montane). These differences are supported by morphological data in Québec/Labrador (Couturier et al. 2010). The discrete status of this DU has mixed support from available genetic data, with some gene flow evident between Eastern Migratory (DU4) and Boreal (DU6) populations in both Québec/Labrador and Ontario/Manitoba (Boulet et al. 2007; McQuade-Smith 2009) and little differentiation between the two migratory George River and Leaf River populations and the Torngat population (DU10; Boulet et al. 2007). However, Courtois et al. (2003a) found more evidence of differentiation between DU4 and DU6, which may be attributable to sampling design, as the study focused on animals from relatively isolated southern ranges in DU6 away from the overlap zone with DU4.

Caribou belonging to DU4 are primarily of the NAL lineage and so have distinct haplotypes from caribou in DU3 (albeit with some introgression of BEL in the George River herd, with preliminary data from Ontario suggesting the same in the Pen Island herd). They do share a common lineage with DU6 animals. Members of this DU, therefore, have a different evolutionary origin from other caribou of a similar ecotype (migratory tundra caribou), with ancestors of the present-day form having moved into the area following the last glaciation from a refugium south of the Laurentide ice sheet. Bergerud et al. (2008) and others hypothesized that caribou from this common gene pool colonized the two distinct habitat options available -boreal forests and tundra - following the retreat of the ice ca. 10,000 years ago, and divided into two ecotypes depending on the nature of the habitat and colonization route. Hence, members of this DU would have evolved convergently in similar tundra-dominated environments as those animals that dispersed from northern refugia into present-day tundra on the Ungava Peninsula and in northern Ontario and Manitoba following the last glaciation. Furthermore, this DU is significant as the only representative of the southern clade (NAL) animals inhabiting tundra habitats, specifically the Arctic ecoregion (Québec/Labrador) and the Hudson Plains ecozone (Ontario and Manitoba). This history places them in an ecological setting that is unique and is likely to have resulted in the aggregated calving behaviour, suggesting that local adaptation has taken place. Current phylogenetic data do not strictly support the significant nature of these caribou from other neighbouring or overlapping ecotypes (DU6, 10 and 11), but there is some evidence of distinctness in nuclear DNA markers and morphology data that is also suggestive of local adaptations.

UNCERTAINTIES TO BE RESOLVED

The greatest uncertainty with DU4 relates to the zone of overlap with DU3 on its western boundary. There has been little research (including genetic sampling) on the Cape Churchill and Pen Island populations relative to those in Québec/Labrador. Hence, the relationships among these populations are uncertain. Cape Churchill caribou are commonly assumed to be similar in origin to the Pen Islands animals (e.g., Gunn et al. 2011; OMNR and ESTR Secretariat 2011), but the Cape Churchill population might be a 'splinter group' of the Qamanirjuaq herd (M. Campbell, pers. comm. 2011) and therefore more appropriately assigned to DU3. This area might be a contact zone between the northern and southern mitochondrial lineages (Bergerud et al. 2008; Boulet et al. 2007), thereby complicating assignment of these populations, particularly Cape Churchill, to either DU3 or DU4.

James Bay represents a significant gap in the middle of DU4 over which there is no known movement between populations, which could render them discrete entities. However, neither phlyogenetic data nor any behavioural or morphological characteristics suggest differences between these populations that might reflect local adaptations, and there is no apparent difference in the ecological settings. Overall, the lack of data directly comparing attributes of the populations on either side of the Bay hampers an assessment of whether these groupings have significant differences that would merit separate DU status.

DU5: NEWFOUNDLAND CARIBOU

Caribou is the sole indigenous ungulate resident of the island of Newfoundland, and its distribution covers most of the island. Although earlier workers had recognized Newfoundland caribou as a distinct subspecies (*R. t. terraenovae*), they were lumped with the woodland caribou subspecies *(R. t. caribou)* by Banfield (1961). Their status as a discrete group was last assessed as the "Newfoundland population of woodland caribou (*Rangifer tarandus caribou*)" by COSEWIC in 2002 (COSEWIC 2002).

LINES OF EVIDENCE

PHYLOGENETICS

Newfoundland caribou have the NAL lineage. Cronin et al. (2005b) surveyed Newfoundland caribou, identifying three haplotypes, all of which were found only in Newfoundland caribou. Among different samples, Eger et al. (2009) found a single haplotype not found elsewhere and reported Newfoundland caribou to be most closely allied with animals in Ontario and Quebec, which as a group had diverged from BEL caribou about 80,000 years ago. Wilkerson (2010) sequenced both cytb and control region of mtDNA caribou within Newfoundland, identifying 32 haplotypes that nested into four distinct clades. Most sampled individuals of Newfoundland caribou showed close relationships to caribou in Québec, and some were also closely related to caribou in Labrador.

GENETIC DIVERSITY AND STRUCTURE

Wilkerson (2010) reported little evidence of genetic structure among populations on Newfoundland as revealed by mtDNA, suggesting little differentiation. There was some evidence that the caribou of the Avalon Peninsula were different genetically from those on the rest of the island of Newfoundland and this separation was attributed to founder events. No microsatellite surveys of Newfoundland caribou have been carried out.

MORPHOLOGY

The morphology of the caribou of the Island of Newfoundland has been described as distinct by Geist (1991), although this conclusion was not based on any statistical analyses. One morphological study was done on one Newfoundland population. In that study, Mahoney and Schaefer (2002) described an overall decrease in body size of adults from the 1960s to the 2000s. Morphological condition of caribou on the island is currently being monitored as part of a larger research and monitoring effort (Humber et al. 2009), but these measurements are not being systematically compared with caribou from other DUs in Canada.

MOVEMENTS AND BEHAVIOUR

There are a number of populations or management units recognized in Newfoundland (Bergerud 1971), most of which seasonally overlap with one another (Mahoney & Virgl 2003). Female caribou display fidelity for specific calving areas, which forms the basis for the current division of island caribou into separate populations. Current radio-collaring efforts are resulting in the identification of new sub-populations as collaring is expanded into previously unexplored areas (P. Saunders, in litt).

Similar to Peary caribou (DU1), Newfoundland caribou have been described as using both aggregated and dispersed calving strategies. For example, the Corner Brook population has been described as representing the dispersed calving ecotype (Mahoney & Virgl 2003), while those elsewhere are more similar to the aggregated ecotype, but only undergoing short migrations within restricted areas (Bergerud 1971; Mahoney & Schaefer 2002). Significantly, most caribou in Newfoundland have shifted from aggregated calving to dispersed calving while undergoing a population decline (since 2000; P. Saunders, in litt).

DISTRIBUTION

The caribou of Newfoundland are separated from those on the mainland of Canada by a significant geographic barrier. Although the Strait of Belle Isle freezes over, and at its narrowest is just 15 km wide, there are no records of movements of individuals between the island of

Newfoundland and Labrador (J. Schaefer, pers. comm. 2010). Newfoundland caribou are found in the Boreal Ecoregion along with Boreal Caribou (DU6).

DISCRETENESS AND SIGNIFICANCE

Newfoundland caribou are discrete from their nearest neighbours on the mainland of Labrador and Québec (DU4 and DU6) due to the barrier of the Strait of Belle Isle whereby movements of caribou between Newfoundland and the mainland have been severely limited for an extended period of time. Populations in this DU are discrete due to mitochondrial sequence differentiation, which has detected no shared haplotypes among the caribou of the island and those of the mainland (DU6) (Cronin et al. 2005b; Eger et al. 2009).

The fixed differences in mitochondrial lineages described above also support their significant status as evidence of phlyogenetic divergence, which Eger et al. (2009) estimated as relatively recent (within 100 yrs) from caribou in Ontario and Québec. Populations in this DU have also persisted on an isolated island where local adaptations are likely to have taken place, including the unique migratory and movement patterns and distinct appearance of these animals (although the latter has not been quantified).

DU6: BOREAL CARIBOU

Boreal caribou are distributed across Canada throughout seven provinces and two territories, extending from the northeast corner of Yukon Territory east to Labrador and south to Lake Superior and some isolated populations in central Quebec. They historically occurred throughout the Maritime Provinces and have lost substantial portions of their southern range from Alberta to Quebec. Boreal caribou were among those caribou classified as woodland caribou (*R. t. caribou*) by Banfield (1961), and were last assessed as the 'Boreal population of woodland caribou (*Rangifer tarandus caribou*)' by COSEWIC in 2002.

LINES OF EVIDENCE

PHYLOGENETICS

Boreal caribou are from the ‘southern’ NAL lineage, which is thought to have colonized the boreal forest and western mountains from the south during the late Pleistocene (Dueck 1998; Cronin et al. 2005b; Eger et al. 2009; Weckworth in prep.). The relationship between sampled boreal populations and other caribou groupings in eastern Canada has been discussed in previous sections. A complete systematic survey of boreal caribou phlyogenetics across their range has not been carried out. However, a coarse evaluation of boreal mtDNA variability suggests some distinction of western vs. eastern boreal herds (Weckworth et al. 2011), a pattern qualitatively supported by morphological data (Banfield 1961). All available evidence indicates that they share haplotypes with the other DUs with which their range overlaps and that they are not monophyletic.

GENETIC DIVERSITY AND STRUCTURE

McDevitt et al. (2009) and Weckworth et al. (2011) sampled the Boreal populations from Alberta and reported significant genetic differentiation between Boreal and neighbouring mountain caribou in Alberta and BC (DU8) with microsatellites. In a broad-scale comparison of microsatellite genotypes of caribou populations across western Canada, Serrouya et al. (in prep.) found 5 boreal caribou populations in Alberta that form two clusters distinct from all mountain caribou (DU 7, 8, and 9), whereas Weckworth et al. (2011) found eight boreal Alberta herds that cluster into four groups. As previously mentioned, Boulet et al. (2007) and Courtois et al. (2003a) reported low levels of differentiation between the Boreal caribou (DU6) of Québec/Labrador and the George River and Leaf River populations (DU4) (Table 2). Similar results were found in Ontario between sedentary boreal caribou and those that aggregate on the coast during calving (McQuade-Smith 2009). Within Boreal caribou, population delineations have in some places been supported by genetic data (Ball et al. 2010). However, other analyses have clustered individuals from larger geographic regions together from Saskatchewan to Manitoba (Ball et al. 2010). In Alberta, McLoughlin et al. (2004) reported low inter-population F_{ST} values of 0 to 0.071 and Weckworth et al. (2011) describe mostly significant pairwise F_{ST} values that range from 0.004 to 0.134.

MORPHOLOGY

The morphological differences between the DUs in Québec and Labrador were discussed with reference to DU4. Butler (1986) compared the general morphology of antlers of caribou belonging to barren-ground and woodland caribou subspecies, arguing that antler size and point placement were a consequence of offensive and defensive tactics during breeding, and not nutritional factors. No systematic morphological survey of Boreal caribou across their complete range and comparisons with overlapping populations from other DUs has been carried out.

MOVEMENTS AND BEHAVIOUR

Caribou dwelling all year in boreal forests are prototypes of the ‘sedentary ecotype’ as described by Bergerud et al. (2008) and defined here in the introduction. From pre-calving to the late summer, females are generally solitary, and space away from one another, most likely to reduce predation risk (Bergerud 1996). They form mixed-sex groups of up to about 20 caribou during other seasons of the year (Metsaranta & Mallory 2007). Activities of female boreal caribou are more independent from conspecifics than migratory tundra caribou from DU3 and DU4, and are coordinated with respect to timing, but not in space (Nagy et al. 2011).

Boreal caribou adopt anti-predator behaviour at the scale of seasonal-range use (Rettie & Messier, 2000, Ferguson & Elkie 2004), rather than the strategy of long-distance migration above the treeline displayed by members of DU3 and DU4. Boreal caribou undertake their largest movements during spring and early winter migration, and are most dispersed and least mobile during the calving season and late winter (Ferguson & Elkie 2004). In contrast to highly variable year-to-year location of their winter ranges, females have fidelity to general calving areas, if not specific sites (Schaefer et al. 2000; Rettie & Messier 2001; Ferguson & Elkie 2004).

Boreal caribou are often managed as distinct populations or as 'conservation units' within provinces or territories. At least 57 individual populations are currently recognized by Environment Canada (2011). In some boreal regions, demographic structure can be evident (Shuter & Rodgers in press). Many, however, behave more like metapopulations within which movements, primarily by males, that facilitate genetic exchange (Ball et al. unpublished data), or populations are continuously distributed across geographies that have no discernible barriers to movement (Environment Canada 2011; Nagy et al., 2011).

DISTRIBUTION

Annual ranges of populations within this DU overlap with the large migratory populations of northern Canada (DU3) and northern Ontario/Manitoba and Québec/Labrador (DU4). In western North America, there is some overlap with DU7 in northeastern BC and DU8 in west-central Alberta. All of these overlaps, however, are confined to winter months when there is little possibility for genetic exchange. For example, the calving and rutting areas of the mountain and boreal populations in west-central Alberta are widely separated by distance and the front range of the Rocky Mountains (Edmonds 1988).

Within this DU, some populations occupy ranges that are isolated from continuous caribou range. For example, in Québec and Labrador there are two isolated populations (Val d'Or and Charlevoix [introduced in the 1970s]); in Ontario there is an isolated population along the coast and islands of Lake Superior (Ontario Woodland Caribou Recovery Team 2008); in Manitoba the Owl Lake population is thought to be isolated, as is the Little Smokey population in western Alberta. With the exception of Lake Superior island populations (for which the range disjunction is natural, although several of these were introduced in the 1980s), all were part of continuously distributed caribou range at one point, and became isolated as a consequence of anthropogenic habitat loss and fragmentation.

Boreal caribou occur across the Boreal ecoregion only.

DISCRETENESS AND SIGNIFICANCE

Boreal caribou are discrete from all other DUs in Canada because any annual range overlap occurs only during winter when there are no opportunities for genetic exchange. Genetic information does not, however, provide much evidence of discreteness either among populations in this DU or between this and neighbouring DUs. Lending some further support to their discrete status, this is the only caribou group found exclusively in the Boreal Ecoregion on a year-round basis; members have evolved aggregation and migration strategies appropriate for this ecological setting, and different from northern caribou that venture below the treeline only during the winter. The isolated populations that exist south of the southern continuous distribution line across Canada reflect range disjunctions that are due to anthropogenic and not natural causes, and therefore these cannot be considered discrete, with the exception of some of the Lake Superior island populations.

Boreal caribou meet a criterion for significance as they belong to the southern clade (NAL lineage), reflecting a deep phylogenetic division between them and migratory caribou from DU3. As discussed above, although they do share a common lineage with DU4 animals, the different behaviours demonstrated by these two groups reflects divergence into two ecotypes following re-colonization of regions uncovered by retreating ice. The significant adaptive behaviour of a dispersed calving strategy therefore marks them as different from the caribou of DU3 and DU4, with which they have some annual range overlap. Other extant DUs with a common phlyogenetic lineage, all of which were classified by Banfield (1961) as belonging to the same subspecies (*R. t. caribou*; DU5, 8, 9, 10, and 11), persist in different ecological settings (alpine habitats and the Island of Newfoundland), which have given rise to local adaptations.

The isolated populations in Québec that are north of the St. Lawrence River, although distinct, are not significant based on available data. The original Charlevoix population became extinct in the 1920s and was re-established from 85 individuals introduced from Opiscotéo Lake, 350 km north of Sept-îles (Banville 1998). The Val d'Or population is also isolated and has unique mitochondrial lineages but the genetic data from Courtois et al. (2003a) did not support the differentiation of this, or the Charlevoix populations from other Boreal caribou within this DU. Therefore, although they may have some discrete traits (i.e., unique haplotypes), there is no evidence that these two populations meet any of the criteria for evolutionary significance (COSEWIC 2009).

UNCERTAINTIES TO BE RESOLVED

While the current boundaries for DU4 and DU6 appear to be reasonable based on ecological information and available data, additional information is required in conjunction with status assessments to refine these boundaries. For example, research and monitoring efforts currently underway in northern Ontario will yield information to define more precisely the northern boundary of DU6 and the southern boundary of DU4 in that province, and the area and degree of overlap.

DU delineations in this report represent the current range in Canada, but some final DU boundaries will have to be reconciled with the historic range in case caribou become re-established in vacant habitat.

DU7: NORTHERN MOUNTAIN CARIBOU

Populations within this DU occur in the northern mountains of Yukon, the southern Northwest Territories, and central and northern British Columbia. Members of this DU were classified by Banfield (1961) as *R. t. caribou* and *R. t. granti.* Most of these populations were last assessed by COSEWIC in 2002 as the "Northern Mountain population of woodland caribou (*Rangifer tarandus caribou*)", but others were included in the assessment of the "Southern Mountain population". This DU extends further south into the Southern Mountain ecological area than does COSEWIC's Northern Mountain population. About 40% of historical caribou range in BC has been lost during the past century (Spalding 2000), some of which belongs to DU7.

LINES OF EVIDENCE

PHYLOGENETICS

In his study of mitochondrial DNA polymorphisms in Yukon caribou, Dueck (1998) demonstrated that all belonged to the Northern mitochondrial lineage (BEL), rather than the NAL lineage that originated from the south. This evidence is contrary to Banfield's (1961) assignment of these northern populations to the woodland caribou subspecies along with most western mountain caribou, although he did recognize that they carried morphological affinities with *R.t. groenlandicus* and *granti*. The phlylogenetic study of Eger et al. (2009) included Yukon samples, which were shown to have most recently diverged from Alaskan caribou, suggesting that Yukon caribou emanated from the Beringian refugium. No samples of boreal or mountain caribou occurring further south were included in the study. Weckworth et al. (2011) similarly demonstrated that caribou from the northern mountains of BC, Yukon, and NWT were most closely related to members of the Barren-ground DU (DU3) and did not belong to the same lineage as samples from boreal (DU6) and mountain (DU 8 and 9) caribou.

Kuhn et al. (2010) completed a phylogenetic study of the Northern Mountain caribou of the Yukon. A phylogenetic tree revealed one distinct clade, which separated the caribou of the Forty Mile, Ibex and Carcross, and Aishihik populations from other populations that were sampled. The majority of the haplotypes were unique to each population, although there were haplotypes shared among the Forty Mile and Aishihik populations. This clade was not better resolved by the widespread phylogenetic analysis (Cronin et al. 2005b; Weckworth et al. 2011).

GENETIC DIVERSITY AND STRUCTURE

In a broad-scale comparison of microsatellite genotypes of caribou populations across western Canada, Serrouya et al. (in prep.) found that all populations from this DU located north of the Peace River form one distinct cluster.

Kuhn et al. (2010) used microsatellite data to detect four genetic clusters within the Northern Mountain populations of the Yukon. Zittlau et al. (2000) assessed microsatellite differentiation among three of the Northern Mountain populations and found high differentiation. Therefore, there is some evidence of genetic distinctiveness within the Northern Mountain DU that likely has been facilitated by topographic features that limit dispersal. Caribou from central Yukon were shown by Zittlau (2004) to maintain high levels of diversity similar to the large Barren-ground populations from DU3, which she hypothesized reflected the admixture of herds in unglaciated regions during the last ice age. Following the retreat of the ice, those animals residing in the ice-free corridor between the Cordilleran and Laurentide ice sheets would have moved east into the alpine regions of the Mackenzie Mountains, and west into Alaska.

MORPHOLOGY

Geist (1991) described the caribou of the Northern Mountains as a distinct subspecies based on antler formations and breeding pelage. This conclusion was not, however, based on any statistical analyses. Kuzyk et al. (1999) investigated body size differences among Boreal (DU6) and Northern Mountain caribou. They found that the shoulder height and hind foot length of Boreal caribou were consistently greater than those of Northern Mountain caribou. In a comparison of seven external body measurements of caribou from seven caribou populations from Yukon, Alaska, Alberta and British Columbia, Gauthier and Farnell (1986) found a clinal variation of decreasing size from south to north, and with little relationship to ecotype or subspecies. Mountain caribou from central Yukon displayed intermediate values of all measures.

MOVEMENTS AND BEHAVIOUR

Movement data, although limited in temporal scope, suggest little intermixing of caribou among western mountain caribou populations (Terry & Wood 1999; Poole et al. 2000; Johnson et al. 2000; 2004; Wittmer et al. 2005; McDevitt et al. 2009; Williamson in prep.). This pattern points to a natural disjunction between substantial portions of the geographic range of this DU, such that movement of individuals between separate regions appears to have been limited for an extended period of time.

Caribou in the northern mountains and adjacent plateaux of western Canada have evolved specialized feeding strategies and migration patterns in response to the prevailing environmental conditions (Heard & Vagt 1998). The relatively gentle and rolling topography of the mountainous western and northern parts of Canada and associated climates and habitats have led caribou to adopt particular patterns of winter movement and habitat use (Warren et al. 1996). In this region where snowfall is low relative to the steep terrain of the southern Rockies, most members of this DU spend winters in mature low elevation lodgepole pine or black spruce forests or on high wind-swept slopes feeding primarily on terrestrial lichen (Stevenson & Hatler, 1985; Johnson et al. 2000). They tend to migrate to higher elevations often over considerable distances, where they spend late spring and summer to calve and forage (Boonstra & Sinclair 1984; Cichowski 1989; Gullickson & Manseau 2000; Gustine et al. 2006). Most populations of Northern Mountain caribou are relatively small and sedentary, with individuals wintering in small groups. They generally employ the calving strategy of moving to high elevations on open sub-alpine ridges, spacing away from conspecifics and predators (Bergerud & Page 1987; Bergerud 1996).

DISTRIBUTION

Two of the Northern Mountain populations in the Yukon (Hart River and Bonnet Plume) have annual ranges that overlap the winter range of the Porcupine caribou population (Yukon, DU3). In addition, the ranges of two populations (Redstone and Nahanni) in NWT extend eastwards into the range of Boreal caribou (DU6); some range overlap is also evident with the caribou of the southern mountains (DU8 and DU9). The geography of these intersecting DUs require more clarification (see Uncertainties to be Resolved).

Relative to other western mountain caribou (DU 8 and 9), members of this DU are found in dry sub-boreal montane ecosystems and use pine-dominated habitats during winter (Frid 1998; Johnson et al. 2000; Florkiewicz et al. 2006). Although Northern Mountain caribou were first recognized by COSEWIC as a Nationally Significant Population (DU) in 2000 (reconfirmed in 2002), the delineation between this and the Southern Mountain population was made on the basis of National Ecological Area boundaries (COSEWIC 2002). This division, however, is not an accurate reflection of Northern Mountain caribou habitat associations, which would be easier to recognize at a finer scale of mapping (e.g., ecotype; Hatter et al. 2004). This distinction has been more appropriately recognized by British Columbia's classification of 'Mountain' and 'Northern' caribou (Stevenson & Hatler 1985), which is not analogous to COSEWIC's DU structure in this part of Canada.

This Northern Mountain DU falls within both the Northern Mountain Ecoregion and the northern part of the Southern Mountain Ecoregion, where Central (DU8) and Southern (DU9) Mountain caribou are also found.

DISCRETENESS AND SIGNIFICANCE

Individual populations of Northern Mountain caribou are generally discrete from one another and adjacent populations, including those recognized as members of other DUs. The Northern Mountain DU shares a boundary or limited overlap with the Central (DU8) and Southern (DU9) Mountain caribou and with Barren-ground (DU3) and Boreal caribou (DU6). However, these boundary areas are limited and there is little inter-mixing of caribou. Genetic work from this area supports the notion of a high level of differentiation in these mountain environments.

The Northern Mountain DU is phylogenetically divergent from boreal and southern mountain caribou populations, and is therefore evolutionarily significant relative to DU6 and DU9. The extensive studies by Kuhn et al. (2010) and Weckworth et al. 2011 found no evidence of NAL in the Northern Mountain population. By contrast, caribou in the Central Mountains (DU8) are both BEL and NAL (McDevitt et al. 2009). Although members of DU7 are thought to have a similar evolutionary origin to Barren-ground caribou (DU3), their persistence in alpine habitats of the northern mountains has given rise to evolutionarily significant local adaptations that distinguish them from migratory tundra caribou (DU3).

UNCERTAINTIES TO BE RESOLVED

Further research is required to resolve both the northern and southern boundaries of this DU. Assignment of some populations into this or adjacent DUs (DUs 3, 6, and 8) remains uncertain due to lack of comparative analyses and overall poor understanding of the ecology and evolutionary origin of mountain populations. Some evidence from both genetic studies and radio-collaring suggest the Peace River to be an important nexus of separation between DU7 and DU8 (Serrouya et al. in prep.; McLoughlin 2004).

DU8: CENTRAL MOUNTAIN CARIBOU

Populations within this DU occur along the eastern side of the Rocky Mountains in west-central Alberta and east-central BC; some populations are shared between the two provinces. Members of this DU were classified by Banfield (1961) as *R. t. caribou.* All populations were last assessed by COSEWIC in 2002 within the 'Southern Mountain population' of woodland caribou (*Rangifer tarandus caribou*). This DU is therefore new to COSEWIC, representing a division of the previous Southern Mountain 'population'. The southern-most remnant population in this DU (Banff) was extirpated in 2009 (ASRD & ACA 2010).

LINES OF EVIDENCE

PHYLOGENETICS

McDevitt et al. (2009) carried out the most widespread sampling of individuals in this DU. Similar to other members of the woodland caribou subspecies, the sampled populations were primarily of the NAL, but included some introgression of BEL. In addition, some populations in this DU originated from the BEL lineage. McDevitt et al. (2009) suggested this as evidence for a “hybrid swarm” of BEL and NAL caribou within the ice free corridor that appeared along the eastern front of the Canadian Rockies producing a unique, mixed gene pool at the end of the Wisconsin glaciations ca. 14 000 years ago. Animals of the BEL lineage from the North migrated along an ice-free corridor along the eastern slopes of the Rockies and came into contact with members of the NAL lineage that were moving from refugia south of the ice sheets and seeking appropriate habitats as the ice sheets receded. McDevitt et al. (2009) theorized that the limited migratory ability of members of the southern clade would have resulted in minimal spread northward, which instead took place in tandem with the post-glaciation recolonization of coniferous forests. This would similarly explain the phylogenetic relationship of DU7 as being predominately BEL in origin.

GENETIC DIVERSITY AND STRUCTURE

McDevitt et al. (2009) reported high differentiation that were significant ($p<0.05$) among populations of the Central Mountain area using mitochondrial data (F_{ST} 0.018 – 0.5619) and microsatellite data (F_{ST} 0.01-0.09). Serrouya et al. (in prep.) included several populations from this DU in their microsatellite genotype study of western Canadian caribou, but grouped three of them together (Kennedy/Quintette/Moberly) and found that one (Jasper) was not well-classified in any cluster. Conversely, Weckworth et al. (2011) describe Jasper and Banff populations from DU8 and the Columbia North herd of DU9 to cluster together in a putative meta-population, although they analyzed only this single herd from DU9. They did, however, confirm a genetic distinction between northerly distributed DU8 herds from those in DU7. Serrouya et al. (in prep.) found the Peace River to be an important source of genetic separation that represents a significant natural disjunction and probable boundary between this DU and DU7.

MORPHOLOGY

No detailed morphological study of Central Mountain caribou has been carried out.

MOVEMENTS AND BEHAVIOURAL ECOLOGY

Caribou populations within this DU are largely isolated from the Northern Mountain caribou (DU7) to the north and west, Boreal caribou (DU 6) to the east and Southern Mountain caribou (DU 9) to the west and south. This isolation is known from extensive radio-telemetry monitoring conducted over many years (D. Seip, in litt.; D. Hervieux, in litt.). There is no evidence of caribou crossing the Peace Arm separating the Moberly herd (DU8) and the Graham herd (DU7; D. Seip, in litt.). In addition to spatially discrete geographic and/or seasonal distributions, DU8 caribou are also isolated from both DU9 and DU6 caribou due to dramatically different ecotypic adaptations and behavioural patterns (D. Seip, in litt.; D. Hervieux, in litt.).

The annual migrations of Central Mountain caribou are very different from Southern Mountain caribou (DU 9) and from the annual movements of the dispersed calving/sedentary Boreal caribou (DU 6) (Saher & Schmiegelow 2004; Williamson in prep). Most caribou populations in the Central Mountains undertake seasonal elevational migrations similar to populations of the Northern Mountains. In recent years (or decades) some other Central Mountain populations are entirely or partially confined to mountainous areas during winter (D. Hervieux, in litt.; Williamson in prep.), probably in response to unfavourable anthropogenic habitat changes on former low elevation winter ranges (D. Hervieux, unpublished data). In general, Central Mountain caribou disperse to calve at high elevations on the eastern slopes of the Rocky Mountains and winter in low-elevation coniferous forests on the boreal plains or foothills along the eastern slopes of the Rocky Mountains, where terrestrial lichens are accessible (Saher & Schmiegelow 2004). DU8 caribou form small groups by late summer that range across montane habitats (Williamson in prep; Edmonds 1988). Group sizes typically increase by the rut in mid-

October and then return to smaller groups as animals disperse to lower elevation forested winter ranges (Edmonds 1988).

In contrast to the Northern Mountain caribou, populations within DU 8 range across both boreal and montane habitats located on the eastern-side of the Rocky Mountains and are more consistent in their altitudinal migrations during summer. When compared to the Southern Mountain caribou (DU9), the intra-montane populations of the Central Mountain DU are found across much drier ecosystems with less snow pack and snow crust/consolidation, where foraging for terrestrial forage is more dominant during winter.

DISTRIBUTION

There is no overlap over most of the Southern Mountain caribou (DU9) and Central Mountain caribou (DU8) ranges, except in the most northerly area where the Hart Ranges population (DU9) partially overlaps with the Kennedy, Quintette, Bearhole/Redwillow, and Narraway populations in DU8. However, this range overlap is almost entirely in summer, when those DU8 herds use the more central portions of the Rocky Mountains. In winter, the Hart Ranges caribou migrate west and winter in old-growth subalpine forest, Kennedy Siding caribou migrate to their low elevation pine winter range, and Quintette, Bearhole/Redwillow, and Narraway caribou migrate east to windswept alpine ridges or low elevation boreal forest winter range. There is almost no range overlap between DU8 and DU9 caribou in rutting areas or on winter ranges. Because the migration to winter ranges occurs prior to the rut, caribou in these DUs have little opportunity for genetic exchange. For example, the Kennedy caribou rut on the low elevation pine winter range while the Hart Ranges caribou rut in high elevation subalpine forests to the south (D. Seip, in litt.). Some annual range overlap occurs between the A La Peche population and the boreal Little Smokey herd in west-central Alberta, but this overlap is strictly in winter (Edmonds 1988) and is periodic occupancy of the same area by only a few individual animals (D. Hervieux, unpubl. data). Weckworth et al. (2011) found some evidence for dispersers between the Little Smokey (DU6) and A La Peche (DU8) herds, but microsatellite data confirmed a prominent and significant genetic distinction between them.

Central Mountain caribou are confined to the Southern Mountain ecoregion where Southern Mountain caribou (DU9) and Northern Mountain caribou (DU7) are also found, and may use areas within the Boreal ecoregion.

DISCRETENESS AND SIGNIFICANCE

The Central Mountain population is discrete from DU6, DU7 and DU9 due to the natural disjunction between species' geographic range and/or the annual distribution of the animals from individual populations. In addition, significant behavioural and ecotypic differences (which are assumed to be inherited traits) contribute to the discreteness of DU8 caribou. Genetic evidence and observations of movement and range overlap suggest that these populations are highly structured with limited mixing both within the DU and among populations found in adjacent DUs (DUs 6, 7, and 9; McDevitt et al. 2009; Williamson in prep.; Serrouya in prep.). In addition, McDevitt et al. (2009) found that the caribou of the Southern

Mountains had both the BEL and NAL lineages, and were therefore discrete from the DU7 caribou of the Northern Mountains (BEL only, Kuhn et al. 2010), and from Boreal caribou (DU6). The only other caribou that are likely to have a mixture of these lineages, and that display similar behavioural ecology are found in northern Québec and Labrador (Torngat Mountains) on the other side of the continent.

With respect to evolutionary significance of this DU, the phylogenetic lineages of Central Mountain caribou is a mixture of NAL and BEL that should be regarded as a unique gene pool with post-glaciation origins (McDevitt et al. 2009). DU8 populations on the east side of the Canadian Rockies have evolved in a unique ecological setting relative to other montane habitats in western Canada, which has given rise to some local adaptations. In comparison to caribou in DU7, unique ecological aspects for the ranges of DU 8 caribou includes occurrence in a different biogeoclimatic climate zone (MacKinnon et al. 1992). Occurrence at the southern extremes of caribou distribution in North America brings caribou into close proximity with unfavourable biogeoclimatic conditions, a highly diverse and generally more abundant and productive complement of other prey species, more abundant and diverse assemblages of predator species, and forest environments that are generally more productive and diverse. Extirpation of these populations would result in a significant north-westward contraction of mountain caribou and reduce the already limited connectivity among populations found within the western mountains (DUs 7 and 9). Furthermore, the North Thompson (see DU9) and Peace Rivers serve as important barriers to movement; hence, loss of the Central Mountain caribou populations would result in a significant gap in caribou distribution. In the case of the Central Mountain DU, this would represent a cluster of populations that are the joining point for potential long-term N-S and E-W gene flow.

UNCERTAINTIES TO BE RESOLVED

Although the boundaries have never been congruent between provincial and federal mountain caribou listing and recovery processes, there have previously never been more than two recognized mountain caribou units from western Canada. Therefore, DU8 is a novel grouping for caribou in Canada. Accordingly, despite the considerable lines of evidence listed above, few comparative studies have been designed to fully test for all aspects of discreteness and significance relative to adjacent DUs. For example, genetic projects in progress (Serrouya et al. in prep; Weckworth et al. 2011) can only partially inform this decision at this juncture. Evidence should be tested as it becomes available to confirm or refute the delineation of this DU in time for its COSEWIC status assessment. As discussed above, the northern boundary of this DU requires resolution.

Given the contraction of 60% of Alberta's caribou range (Hummel & Ray 2008), it is important to reconcile the current DU boundaries with the existing distribution of caribou as well as habitats previously occupied by extant and extirpated (e.g., Banff) populations. This will help ensure that future recovery and restoration actions for caribou coincide with past distribution and the appropriate evolutionary units.

DU9: SOUTHERN MOUNTAIN CARIBOU

Populations within this DU occur in central and southeastern BC. Members of this DU were classified by Banfield (1961) as *R. t. caribou.* All populations were last assessed by COSEWIC in 2002 as the 'Southern Mountain population of woodland caribou (*Rangifer tarandus caribou*)', but this also included some populations from the Northern and Central Mountain DUs (DU7 and 8). About 40% of historical caribou range in BC has been lost during the past century (Spalding 2000), most of which belongs to this DU.

LINES OF EVIDENCE

PHYLOGENETICS

No phylogenetic study has included samples from caribou of this DU.

GENETIC DIVERSITY AND STRUCTURE

McDevitt et al. (2009) sampled one caribou population belonging to this group. He reported no differentiation between this group and those of Northern (DU7) or Central (DU8) caribou. It should be noted, however, that the sampled population was at the northern extent of the range of DU9. In addition (Weckworth et al. 2011) showed close genetic affiliation of herds within DU8 and the Columbia North herd of (DU9), and proposed a historic meta-population that included Columbia North, Banff, and Jasper herds. More extensive genetic surveys have revealed that populations within the Southern DU exhibit pronounced structuring, likely as a result of small populations that have suffered more rapid genetic drift (R. Serrouya in prep.). In this case, the genetic distance between some adjacent caribou populations within this DU were much larger than differences between this and other DUs. Six populations in the Columbia North area had low but significant differentiation from caribou north of the Peace River (F_{ST} = 0.08) and those in the Purcells were distinguishable from the caribou of the Southern Mountains ($F_{ST} > 0.13$ in all cases). Overall, samples from across British Columbia and Alberta separated into five genetic clusters (Structure analysis). Clusters 1, 2, and 3 represented the populations from the Southern Mountains, Central Mountains, and Northern Mountains DUs, while clusters 4 and 5 were Boreal caribou (DU 6) (R. Serrouya, in prep.).

MORPHOLOGY

No morphological data are available for Southern Mountain caribou.

MOVEMENTS AND BEHAVIOUR

There are 18 distinct populations of Southern Mountain caribou isolated from one another by anthropogenic habitat fragmentation and between which no dispersal has been detected (Wittmer et al. 2005; Apps & McLellan 2006; Van Oort et al. 2011). Furthermore, many of these caribou populations are found across steep mountainous terrain. Even without reduced connectivity resulting from anthropogenic disturbance, habitat change, and altered predator-prey dynamics, population isolation is likely greater when compared to the range of Northern and Central Mountain caribou.

Caribou belonging to this DU have a distinct behaviour related to their use of habitats found in steep, mountainous habitats with deep snowfall (with an accumulated snowpack of 2-5 m). These extreme snow conditions have led to a foraging strategy that is unique among cervids, that is, the exclusive reliance on arboreal lichens for 3-4 months of the year. Because these lichens are most abundant on old growth conifers, these caribou are strongly associated with conifer forests that are >250 yrs old (Apps et al. 2001). These caribou winter at high elevations, and feed exclusively on arboreal lichens found on standing or wind-fallen conifer trees of late seral stage (Terry et al. 2000). During spring, these caribou seek out vascular plants in valley bottoms and return to high-elevation mountainous habitats to calve and forage during summer (Heard & Vagt 1998; Apps et al. 2001; Wittmer et al. 2005; Kinley et al. 2007). Southern Mountain caribou also undertake altitudinal migrations as many as four times a year. This behaviour is quite different from that of the Central Mountain caribou (DU8) with which their range has a small degree of overlap. Like most Central, Northern, and Boreal caribou, these animals have a dispersed calving strategy.

DISTRIBUTION

There is some overlap between the annual ranges of some populations in this DU and those of Central Mountain caribou (DU8) at the far north of the Southern Mountain caribou distribution (i.e., Parsnip and Kennedy populations), although not during the rut or mating season. However, the northern boundary of this DU is uncertain (Serrouya, in prep). Microsatellite analyses suggest, at least historically, that Columbia North animals had some level of gene flow with adjacent DU8 herds to the east (Weckworth et al. 2011). For the majority of Southern Mountain caribou populations, there is no opportunity for demographic rescue or immigration by caribou from other DUs.

Similar to Northern Mountain caribou, a Southern Mountain population was recognized by COSEWIC in 2000, but with boundaries that conformed to the Southern Mountain National Ecological Area (COSEWIC 2002) -- not an accurate reflection of the unique habitat of Southern Mountain caribou. The distinction between northern and southern mountain has been more appropriately recognized by British Columbia's classification of “Mountain” and “Northern” caribou (Stevenson & Hatler 1985), which is not analogous to COSEWIC's DU structure in this part of Canada. As discussed previously, the Southern Mountain National Ecological area also includes populations of caribou found in drier ecosystems that forage on terrestrial lichens during winter and that were assigned in this report to the Northern Mountain DU (DU7) (Hatter et al. 2004). Members of the Southern Mountain DU live and are adapted, at least behaviourally, to specific environments characterized by high-elevation forest communities that support abundant arboreal lichens.

DISCRETENESS AND SIGNIFICANCE

Southern Mountain caribou are discrete from the closest Central Mountain caribou (DU8) based on evidence for inherited traits. The steep terrain and high level of precipitation of the inner mountains of British Columbia has resulted in behavioural strategies and distributional patterns that are a response to a single forage type during winter: arboreal lichens. The discrete nature of the populations within this DU is confirmed by genetic evidence demonstrating population structure both within the DU and compared to populations of Boreal (DU6), Central Mountain (DU8), and Northern Mountain (DU7) caribou (R. Serrouya in prep.).

This group of caribou differs markedly from other caribou, including those in the adjacent DU8, as they have persisted in an ecological setting unique to the species that has given rise to local adaptations. Continued loss of these most southerly populations of caribou would result in an extreme northward contraction of the species range, and the certain disappearance of caribou in adjacent Idaho, which are classified as endangered under the U.S. Endangered Species Act.

UNCERTAINTIES TO BE RESOLVED

There is some uncertainty in the northern boundary of the DU and the inclusion of the Hart Range, Jasper, and Banff populations in DU7 or DU9. Because 40% of BC's caribou range has been lost over the past century (Spalding 2000), it will be important to ensure that DU7 and DU9 boundaries are clear relative to historic caribou range.

DU10: TORNGAT MOUNTAINS

This DU is comprised of a single population in the Torngat Mountains of northern Québec and Labrador. This population was included among the woodland caribou subspecies (*R. t. caribou*) identified by Banfield (1961). Members of this DU have never been assessed by COSEWIC.

LINES OF EVIDENCE

PHYLOGENETICS

No phylogenetic study has included samples of caribou from the Torngat population, although they are assumed to have a similar origin to the neighbouring Eastern Migratory populations (DU4).

GENETIC DIVERSITY AND STRUCTURE

Boulet et al. (2007) included genetic data from the caribou of the Torngat Mountains (albeit a small sample size), and reported low (Fst values of 0.017 to 0.040) but significant levels of differentiation between Torngat caribou and Boreal caribou (DU6) in northern Québec and Labrador. However, Torngat Mountains caribou were not significantly different from George

River and Leaf River populations, which belong to the migratory ecotype that aggregate at calving (DU4).

MORPHOLOGY

A detailed morphological assessment of the caribou in northern Québec and Labrador by Couturier et al. (2010) comparing measurements of hind foot length, girth, and body length revealed significant differences between animals from DU4 (George River and Leaf River) and DU6 and those from this DU. Bergerud et al. (2008) remarked that while the behaviour of Torngat animals is similar to boreal caribou in that they disperse at calving, their antler morphology is much more like migratory caribou.

MOVEMENTS AND BEHAVIOUR

Caribou in the Torngat Mountains belong to a distinct montane ecotype and, despite their southern range overlapping occasionally with that of the George River population, telemetry has revealed them as a distinct population with discrete movements (Schaefer & Luttich 1998).

Torngat Mountain caribou exhibit behaviour similar to most mountain-dwelling caribou of British Columbia, Yukon, and Northwest Territories, in that they undertake altitudinal migrations and disperse to calve alone in the sub-alpine and alpine areas within their population range. Telemetry data suggest that distances traveled between seasonal ranges are one-sixth that of neighbouring George River caribou (I. Schmelzer, in litt.). The differences among these and the other ecotypes of caribou in Northern Québec and Labrador (DU4) were discussed previously.

DISTRIBUTION

The George River population's annual range overlaps with the southern portion of that of the Torngat Mountain population, although seasonal range overlap is minimal, particularly during winter. The Torngat Mountain population has a disjunct range from other caribou DUs of the montane ecotype (DU 7, 8, 9, and 11). The Torngat Mountain population is the only montane ecotype caribou found in the Arctic ecoregion.

DISCRETENESS AND SIGNIFICANCE

Torngat Mountain caribou are discrete from the aggregated calving caribou of Northern Québec and Labrador (DU4), based primarily on what can be assumed to be inherited behavioural and morphological traits; they have not, however, been shown to be genetically distinguishable. Although there is some overlap in the annual ranges of populations within these two DUs and some evidence of genetic exchange, seasonal ranges (particularly in winter) are mostly discrete. Torngat caribou have a disjunct range from the other populations of montane caribou (DU7 and DU8) in western Canada and on the Gaspé Peninsula (DU11); they are genetically distinct from the latter.

The Torngat Mountain caribou are of the montane ecotype in the eastern Arctic and as such dwell in an ecological setting that has given rise to local adaptations. They are the only population of the southern mitochondrial lineage that spend the entirety of their annual range in the Arctic Ecoregion.

UNCERTAINTIES TO BE RESOLVED

Until recently, relatively little attention has been paid to this population, but this situation has recently shifted, with the recent launch of a radio-telemetry program, genetic research, and ATK gathering (Torngat Plant and Wildlife Co-Management Board, in litt.). Evidence should be tested as it becomes available to confirm or refute the delineation of this DU in time for its COSEWIC status assessment.

DU11: ATLANTIC-GASPÉSIE CARIBOU

This DU is comprised of one population (also called Gaspé caribou), most of the annual range of which is in the Gaspésie Park on the Gaspé Peninsula of Québec. This population was included among the woodland caribou subspecies (*R. t. caribou*) by Banfield (1961). This population was last assessed by COSEWIC in 2002 as the 'Atlantic- Gaspésie population of woodland caribou (*Rangifer tarandus caribou*)'.

LINES OF EVIDENCE

PHYLOGENETICS

No phylogenetic study has included samples from these caribou.

GENETIC DIVERSITY AND STRUCTURE

In a comparison among seven populations (including one migratory herd [George River]) of three caribou ecotypes in Québec, Courtois et al. (2003a) found evidence of that Gaspésie caribou were significantly differentiated genetically from all six other populations (F_{ST} ranging from 0.103-0.172). Røed et al. (1991) also sampled Gaspésie caribou as part of their genetic survey of transferrin variation in caribou in Eastern Canada. They found shared transferrin alleles among the Gaspésie population, the George River, and Leaf River populations and very low differentiation between the Gaspésie population and the leaf River caribou (D_S 0.086) when compared to the other populations from Québec (D_S 0.341).

MORPHOLOGY

No morphological data are available for Gaspésie caribou.

MOVEMENTS AND BEHAVIOUR

The caribou of Gaspé Peninsula are of the montane ecotype. They undergo seasonal altitudinal migrations to alpine habitat, but these are predominantly confined to Gaspésie Park.

The Gaspésie caribou have divergent behaviour from the Boreal caribou (DU6) further north as distinguished by their exclusive use of mountainous habitats. They are adapted to the alpine habitat of the Chic-Chocs Mountains, and even if no barriers prevent them from escaping the peninsula through the southwest, no cases of long-distance dispersal have been documented.

DISTRIBUTION

The Gaspésie population of southern Québec is the sole population of caribou remaining south of the St. Lawrence River (Ouellet et al. 1996; Mosnier et al. 2003; Courtois et al. 2003b), with other caribou from the region having disappeared by the 1920s. Over a century ago, caribou freely inhabited boreal and Acadian forest landscapes throughout the north-eastern U.S., New Brunswick and Nova Scotia, a region that has been highly transformed by humans. Gaspésie caribou have a disjunct range from all other caribou, with a natural boundary of the St. Lawrence River, which has swift currents and is not considered to be passable at any time of the year between the north and south shores of Québec. Caribou on the Gaspé Peninsula were most numerous to the south and southeast of Québec City (Courtois et al. 2003b). These are the only caribou residing in the Atlantic ecoregion.

DISCRETENESS AND SIGNIFICANCE

Gaspésie caribou are discrete by virtue of their genetic differentiation from other nearby caribou populations. There is also a natural range disjunction between them and all other extant caribou in Canada, predominantly due to the natural barrier of the St. Lawrence River directly to the north. Accordingly, movement of individuals between populations has been severely limited for more than 100 years. The Gaspésie caribou are montane caribou and as such they are discrete from the Boreal caribou (DU6), which are the most geographically proximate caribou group.

The Gaspésie caribou population is evolutionarily significant because it represents the only caribou that remain in the Atlantic ecoregion. In this regard, this population has persisted in a setting that is unusual and unique to caribou, and is the only surviving remnant of a formerly continuous population across the Gaspé Peninsula, the Maritimes, and northern New England. The loss of these caribou would result in an extensive gap in the range of the species in Canada.

DU 12: DAWSON’S CARIBOU

This DU is comprised of caribou that were formerly resident of the northwestern part of Graham Island, the northernmost of the two largest islands of Haida Gwaii. Dawson’s caribou was classified as a unique subspecies (*R. t. dawsoni*) by Banfield (1961). The population was reconfirmed as extinct by COSEWIC in 2000 (see COSEWIC 2002).

LINES OF EVIDENCE

PHYLOGENETICS

No phylogenetic study has included samples from Dawson’s caribou.

GENETIC DIVERSITY AND STRUCTURE

Byun et al. (2002) conducted genetic analyses of material from skins and skulls from three museum specimens of caribou from Haida Gwaii and conspecifics from western Canada. The results, involving partial sequences from the mitochondrial gene cytochrome b, suggested that this population was not genetically distinct from caribou in northern BC and Alaska.

MORPHOLOLOGY

Banfield’s (1961) original subspecies designation of this already-extinct caribou was made on the basis of morphological characteristics. Although these measurements were based on only a few specimens, much has been made of the small stature, pale pelage , and poorly developed antlers of this entity (Byun et al. 2002). The conflicting evidence as to whether these divergent characteristics represent local adaptations of a glacial relict or are simply indicative of its insular environment cannot now be resolved (Spalding 2000; Byun et al. 2002). Dawson caribou was one of multiple taxa endemic to these islands, all of which display morphological distinction from their mainland counterparts (Byun et al. 2002).

MOVEMENTS AND BEHAVIOUR

There is no information on movements, behaviour or life history traits of caribou from Haida Gwaii. Banfield (1961) described the habitat as treeless bogs in humid boreal forest and similar to other boreal caribou. He also indicated that indigenous peoples of Haida Gwaii were not particularly familiar with this animal, which is most likely explained by their tie to coastal areas and caribou occupancy of dense forests. However, evidence from caves and middens indicate that caribou existed on Haida Gwaii for at least 12,000 RCBYP, a period that spans the entire time the islands were separated from the mainland by the inundation of the Hecate Lowlands (Mackie et al. 2011).

DISTRIBUTION

Caribou occurred on Haida Gwaii, the most isolated group of islands in the Pacific Northwest known for its endemic flora and fauna, until the early 1920s (Byun et al. 2002). These caribou belonged to the Pacific National Ecological Area. Other caribou that once occupied this ecoregion on the western coast of British Columbia disappeared at about the same time.

DISCRETENESS AND SIGNIFICANCE

Because caribou from Haida Gwaii are no longer extant, as is the case for other caribou that formerly occupied the same Ecological Area on the mainland, it is difficult to ascertain definitively whether the putative DU is truly discrete and significant. Genetic evidence suggests that Dawson`s caribou is not a discrete entity, but their morphology suggests substantial divergence. The latter, however, is based on only three specimens. Furthermore, there is a natural disjunction between Haida Gwaii and the mainland of British Columbia that most likely prevented movement of individuals since the last glacial maximum, with archaeological evidence to suggest that caribou were present on the island throughout this period. This makes a plausible case for the evolutionary significance of this population because of its persistence in the unusual ecological setting of the Haida Gwaii islands, which is home to several other endemic variants of mainland species.

PROPOSED DU STRUCTURE FOR CARIBOU IN CANADA

There are twelve designatable units for caribou in Canada (Figure 4; Table 3). All 8 pre-existing "Nationally Significant Populations" were maintained, although the boundaries of two (Northern Mountain [DU7] and Southern Mountain [DU9]) were modified considerably. Four new DUs were created, three of which included caribou populations that have never been assessed by COSEWIC, and a fourth (Central Mountain [DU8]), which included populations that had been previously assessed as DU9 (Table 4). Most DUs will require extra scrutiny of population assignments around their boundaries to finalize DU limits during the COSEWIC status assessment process that will follow. Further radio-telemetry and genetic study, much of which is ongoing as of this writing, and the inclusion of ATK, may bring evidence for future identification of DUs within this present set, particularly in DU3 (Barren-ground).

As would be expected of this broadly-distributed species, almost all evidence used to assess the discreteness and significance of each DU (Table 5) was limited to portions of Canada, making cross-comparisons of all DUs across the country generally impossible. The foundation of all DU designations was related to the diversity of ecological settings across the range of this species, to which populations have adapted, at least behaviourally. Although morphological differences between many neighbouring DUs are often remarked upon, only a few studies have produced quantifiable results and were used as supporting evidence for some DUs.

Genetic studies on this species have multiplied during the past decade, and were used in many cases to support discreteness of caribou DUs. Due to the preponderance of evidence for at least two distinct phylogenetic lineages for North American caribou, results from mitochondrial studies were useful for testing the significance of many DUs. Such evidence, however, did not provide unequivocal support for this DU structure. This can in part be explained by quantity or quality of information. For example, there are populations in several DUs that have never been included in phylogenetic studies, and the distribution of samples and use of different regions of the mitochondrial genome within and across the completed studies limited the ability to compare DUs on this basis. For several DUs, on the other hand, the current patterns of morphological and genetic variation also reflect more recent conditions. For small populations or bottlenecks that have been driven by extreme climatic conditions (e.g., Peary, DU1) or anthropogenic disturbance (e.g., Southern Mountain, DU9), genetic drift has led to obvious genetic differentiation. On the other hand, in regions where populations have remained large in size, evolutionary selection has likely been less intense, genetic drift has been slow to occur, and populations exhibit high genetic variability as a result.

DU designations were made when several lines of evidence provided support for their discreteness and significance. Consequently, although the full weight of evidence was stronger for some than for others, the level of confidence in this overall DU structure is high. As additional data become available, it is possible some of the putative DUs we considered and dismissed might find additional support. We also note that some DU boundaries are not at present well-resolved even though the caribou DUs are supported.

KNOWLEDGE GAPS

ABORIGINAL TRADITIONAL KNOWLEDGE

This report does not formally include ATK as an important source of information for distinguishing different kinds of caribou in Canada, although it was reviewed by most Wildlife Management Boards. Knowledge of this type to be incorporated during the status assessment process will not only be useful for confirmation of this DU structure, but will be particularly important in local areas where caribou DUs overlap to help identify boundaries and assign populations.

PHYLOGENETICS AND MITOCHONDRIAL DATA

There has been no national survey of caribou using a single part of the mitochondrial genome. Research should be focussed on identifying areas where one of the regions has not been sequenced and filling in those data gaps (e.g., cytochrome b in western mountain caribou). Several laboratories are addressing this question and sequences will be made available on GenBank for comprehensive comparisons.

Special attention should be paid to phylogenetic relationships. In particular, additional research is needed on the origin of caribou on Coats and Southampton Islands, the eastern migratory populations together with Torngat Mountains (DU4 and 10), and Southern Mountain caribou

(DU9). Phylogenetic data should be synthesized into a map for all of Canada to depict haplotype (NAL/BEL) distribution.

GENETICS

More efforts will help to fill in gaps in surveyed ranges and in sampling individuals from neighbouring DUs in the same study. Even better would be a cross-Canada survey of caribou using a single set of microsatellites. The strong female bias in genetic sampling will need to be balanced by more collection of male samples, rather than relying on the unreasonable assumption that the two sexes have similar movements and dispersal strategies. The emerging science of ecological genomics should be applied to caribou DUs to determine functional genes that may help provide more precise delineation of DUs and/or particular ecotypes.

MORPHOLOGY

Although much data describing the morphology of caribou have been collected, these are not comparable across the range of the species. Quantitative morphological data that are invariant to population density will allow a comparison of caribou within and among the proposed DUs.

MOVEMENTS

Currently, the spatio-temporal distribution of many populations of caribou are being monitored across Canada. Furthermore, there is an existing rich dataset describing seasonal movements and distribution of thousands of caribou; for some populations, these data exceeds 20 years of monitoring. There is an opportunity to explore these existing data and to collect new data for relatively unknown populations. Efforts should focus on a comparison of individuals from neighbouring DUs with particular attention paid to testing space use strategies relative to population density and general cross-DU ecological factors.

BEHAVIOUR AND LIFE HISTORY TRAITS

Behaviour was included as one of the primary adaptive traits across the range of caribou. Although there have been extensive reports of the behavioural differences among ecotypes future research should focus on collection of further quantitative data for these traits, particularly in the case of the montane caribou and in the zone of overlap between DU4 and DU6. A focus should be placed on evaluating and even quantifying the extent to which behaviours are either heritable or plastic, which will help assessments of their evolutionary significance. Linkages with genomics and long and short-term movements are essential. A comprehensive and consistent scheme for classifying caribou by ecotype should be devised and adopted accordingly.

ACKNOWLEDGEMENTS

Ongoing consultation with the Trent caribou group and Micheline Manseau through the preparation of this report was invaluable. The following persons contributed substantially to the report by providing insight and information or reviewing previous drafts: Ken Abraham, Jan Adamczewski, Al Arsenault, Mark Brigham, Mitch Campbell, Steeve Coté, Serge Couturier, Judith Eger, Marco Festa-Bianchet, Dave Fraser, Anne Gunn, Troy Hegel, Dave Hervieux, Karen Hodges, Chris Hodgson, Martin-Hughes St-Laurent, Jeff Hutchings, Debbie Jenkins, Rebecca Jeppesen, Thomas Jung, Chris Kyle, Marty Leonard, Keri McFarlane, Bruce McLellan, Dennis Murray, Simon Nadeau, Sue Pollard, Bruce Pond, Jim Schaefer, Isabelle Schmelzer, Dale Seip, Robert Serrouya, Rick Taylor, Byron Weckworth, and Greg Wilson. We are grateful to countless others participated in the jurisdictional review process. Jenny Wu (COSEWIC Secretariat) provided important technical assistance. We are also grateful to Kamila Baranowska, Christina Fridgen, Megan Hornseth, Erica Newton, Karen Smith and Tyler VanderMolen for general support.

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Dr. Laura Finnegan is a Postdoctoral Research Fellow and sessional instructor at Trent University. Her PhD is from Trinity College Dublin, where she carried out a conservation genetic assessment of the red squirrel in Ireland. She has been working on caribou for the past two years where she has used genetic data to address a range of questions relating to population delineation, ecotypes and dispersal. She has carried out research on the landscape genetics on a range of species in Canada and Ireland as well as working on large ungulates in Botswana and carrying out independent wildlife contract work in Ireland. Her research interests include conservation, management and landscape genetics of wildlife.

Laura Thompson is a Ph.D. student at Trent University in Peterborough, Ontario and is currently working as a biologist with the U.S. Geological Survey, National Climate Change and Wildlife Science Center in Reston, Virginia. She is interested in genetic variation of wild organisms throughout space and time and how it may be influenced by natural and human-related activities. Laura’s Ph.D. research uses DNA collected from fecal material to quantify and understand factors that are contributing to the genetic structure of woodland caribou in central portions of the Canadian boreal forest.

Dr. Paul Wilson is a Canada Research Chair in DNA Profiling, Forensics and Functional Genomics at Trent University where his research programs examines applied objectives and basic research questions relating to non-human forensic DNA profiling; natural resource management and conservation genetics; and landscape genetics. Dr. Wilson works on a number of species including boreal and Peary caribou, Canada lynx, polar bears, wolves, moose, flying squirrels and Peromyscus.

TABLE 1. COSEWIC assessments of caribou (source: COSEWIC 2011)

Subspecies	"**Ecotype**" or "Population"*	**COSEWIC status (year)**	**Reasons for Designation**	**Schedule/ SARA Status**
Barren-ground x Peary *(R. t. groenlandicus x R. t. pearyi)*	Dolphin & Union population	Special Concern (2004)	numbers have recovered to ca. 25% of population historic size are subject to threats	Schedule 1/ Special Concern
Dawson *(R. t. dawsoni)*		Extinct (2000)	last verified record in 1908	--
Peary *(R. t . pearyi)*		Endangered (2004)	Numbers declined by ca. 72% over the last three generations	Schedule 1/ Endangered
Woodland *(R. t. caribou)*	Atlantic-Gaspésie population	Endangered (2002)	Small isolated population < 200 adults	Schedule 1/ Endangered
Woodland *(R. t. caribou)*	Boreal population	Threatened (2002)	Declines of ≥ 30%	Schedule 1/ Threatened
Woodland *(R. t. caribou)*	Newfoundland	Not a Risk (2002)	---	--
Woodland *(R. t. caribou)*	Northern Mountain population	Special Concern (2002)	Forestry, roads and other developments beginning to affect some herds; some in decline	Schedule 1/ Special Concern
Woodland *(R. t. caribou)*	Southern Mountain population	Threatened (2002)	small, increasingly isolated herds, 13 of 19 in decline, subject to multiple developments, range has shrunk by up to 40%.	Schedule 1/ Threatened

*Previous COSEWIC term for Designatable Unit

TABLE 2. F_{ST} values among herds/local population within calving strategies (Dispersed (Dis) and Aggregated (Agg)) and F_{ST} values among calving strategies and ecotypes (Dis v Montane (Mon), Dis v Agg and Agg v Mon) for caribou sampled in Québec and Ontario.

	Dispersed	Aggregated	Dis v Mon	Dis v Agg	Agg v Mon
Courtois et al. 2003 (QC)	0.016-0.116	n/a	0.103-0.167	0.087-0.172	0.172
Boulet et al. 2007 (QC)	0.018-0.048	0.002	0.017-0.022	0.017-0.038	0-0.005
Wilson et al. unpub (ON)	0.017-0.098	n/a	n/a	0.020-0.030	n/a

TABLE 3. Proposed Designatable Units for Caribou, location, and subspecies and ecotype information.

DU	ADJACENT DUs	SUBSPECIES	DISTRIBUTION	ECOTYPE/CALVING STRATEGY
Peary (DU1)	DU2, DU3	*R. t. pearyi*	Arctic Islands[1] (NWT, NU)	Sedentary/Dispersed
Dolphin and Union (DU2)	DU1, DU3	*R. t. groenlandicus x pearyi*	Victoria Island (NU)	Migratory/Dispersed
Barren-ground (DU3)	DU1, DU2, DU4, DU6, DU7	*R. t. groenlandicus, R. t. granti*	YT, NWT, NU, MB, SK, MB	Migratory (boreal-tundra and tundra-wintering)[1]/Aggregated
Eastern Migratory (DU4)	DU3, DU6, DU10	*R. t. caribou*	QC, NL, ON, MB	Migratory (boreal-tundra)/ Aggregated
Newfoundland (DU5)	DU6	*R. t. caribou*	NL	Sedentary/Dispersed/Aggregated
Boreal (DU6)	DU3, DU4, DU5, DU7, DU8, DU11	*R. t. caribou*	NWT, BC, AB, SK, MB, ON, QC, NL	Sedentary/Dispersed
Northern Mountain (DU7)	DU3, DU6, DU8	*R. t. caribou*	NWT, YT, BC	Montane/Dispersed
Central Mountain (DU8)	DU6, DU8, DU9	*R. t. caribou*	BC, AB	Montane/Dispersed
Southern Mountain (DU9)	DU7, DU8	*R. t. caribou*	BC	Montane/Dispersed
Torngat Mountains (DU10)	DU4	*R. t. caribou*	NL	Montane/Dispersed
Atlantic-Gaspésie (DU11)	DU6	*R. t. caribou*	QC	Montane/Dispersed
Dawson’s (DU12)	DU7	*R. t. dawsoni*	BC	Unknown

*excluding Baffin Island, Coats Island and Southampton (which are included in DU3)

TABLE 4. COSEWIC assessment history of each DU (formerly referred to as 'Nationally Signifiant Populations' by COSEWIC; see Fig 3).

DU	New or pre-existing COSEWIC DU	Comments
Peary (DU1)	Pre-existing	Last assessed in 2003 (COSEWIC 2004)
Dolphin and Union (DU2)	Pre-existing	Last assessed in 2003 (COSEWIC 2004)
Barren-ground (DU3)	New	Never assessed
Eastern Migratory (DU4)	New	Never assessed
Newfoundland (DU5)	Pre-existing	Last assessed in 2002 (COSEWIC 2002)
Boreal (DU6)	Pre-existing	Last assessed in 2002 (COSEWIC 2002)
Northern Mountain (DU7)	Pre-existing (modified)	DU was coincident with Northern Mountain Ecological Area, with a more northern boundary; Last assessed by COSEWIC in 2002 (COSEWIC 2002)
Central Mountain (DU8)	New	Populations in this DU were assessed as Southern Mountain in 2002 (COSEWIC 2002)
Southern Mountain (DU9)	Pre-existing (modified)	DU was coincident with Southern Mountain Ecological Area, with a more southern boundary; Last assessed by COSEWIC in 2002 (COSEWIC 2002)
Torngat Mountains (DU10)	New	Never assessed
Atlantic-Gaspésie (DU11)	Pre-existing	Last assessed by COSEWIC in 2002 (COSEWIC 2002)
Dawson’s (DU12)	Pre-existing	Last assessed by COSEWIC in 2002

TABLE 5. Evidence supporting discrete and significant criteria (following COSEWIC 2009) for DU structure for Caribou (*Rangifer tarandus*). X=available data supported discreteness or significance; += available data contributed some support, O=available data did not support; N=no data were available.

Name of Designatable Unit	**Discrete**					**Significant**			
	Genetic Distinctivenesss	Inherited Trait: Behaviour	Inherited Trait: Morphology	Movements/ range overlap	Eco-geography	Phylogenetcs divergence	Local adaptations to Ecological setting	Only surviving natural occurrence	Irreplaceable/ extensive gap
Peary (DU1)	**X**	**X**	**X**	**X**	**O**	**O**	**X**	**O**	**X**
Dolphin and Union (DU2)	**X**	**X**	**X**	**X**	**O**	**+**	**X**	**O**	**O**
Barren-ground (DU3)	**X**	**X**	**N**	**X**	**O**	**X**	**X**	**O**	**O**
Eastern Migratory (DU4)	**X**	**X**	**X**	**X**	**X**	**+**	**X**	**O**	**O**
Newfoundland (DU5)	**O**	**X**	**+**	**X**	**O**	**X**	**X**	**O**	**X**
Boreal (DU6)	**O**	**X**	**N**	**X**	**X**	**X**	**X**	**O**	**O**
Northern Mountain (DU7)	**X**	**X**	**N**	**X**	**O**	**X**	**X**	**O**	**O**
Central Mountain (DU8)	**X**	**X**	**N**	**X**	**O**	**X**	**X**	**O**	**X**
Southern Mountain (DU9)	**X**	**X**	**N**	**X**	**O**	**N**	**X**	**O**	**X**
Torngat Mountains (DU10)	**X**	**X**	**X**	**O**	**X**	**O**	**X**	**O**	**O**
Atlantic-Gaspésie (DU11)	**X**	**X**	**N**	**X**	**X**	**O**	**X**	**X**	**X**
Dawson’s (DU12)	**O**	**N**	**X**	**X**	**+**	**N**	**X**	**O**	**O**

FIGURE 1. Map of Caribou Distribution (Current and Historical) relative to COSEWIC National Ecological Areas

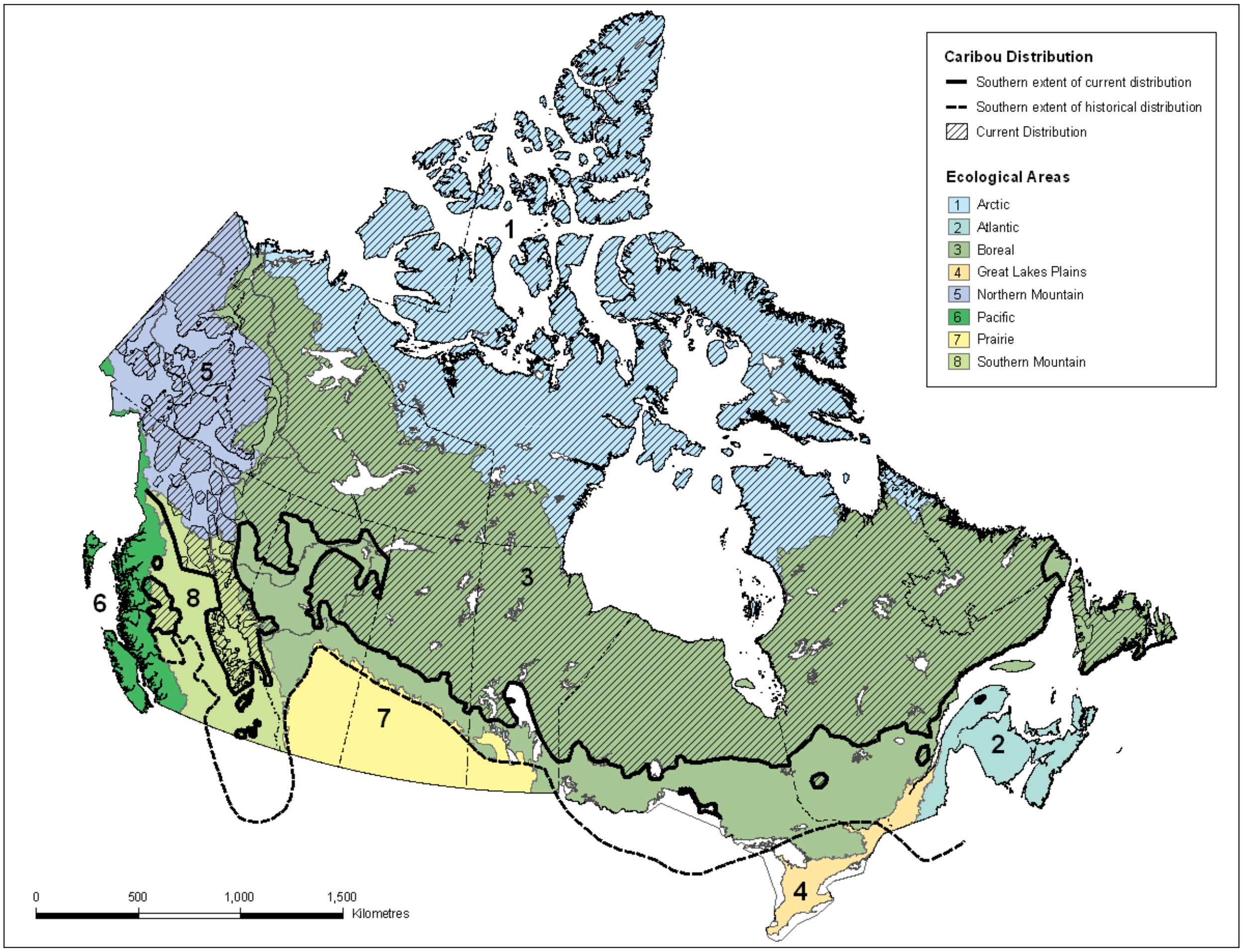


FIGURE 2. Extant caribou (*Rangifer tarandus*) subspecies after Banfield (1961)

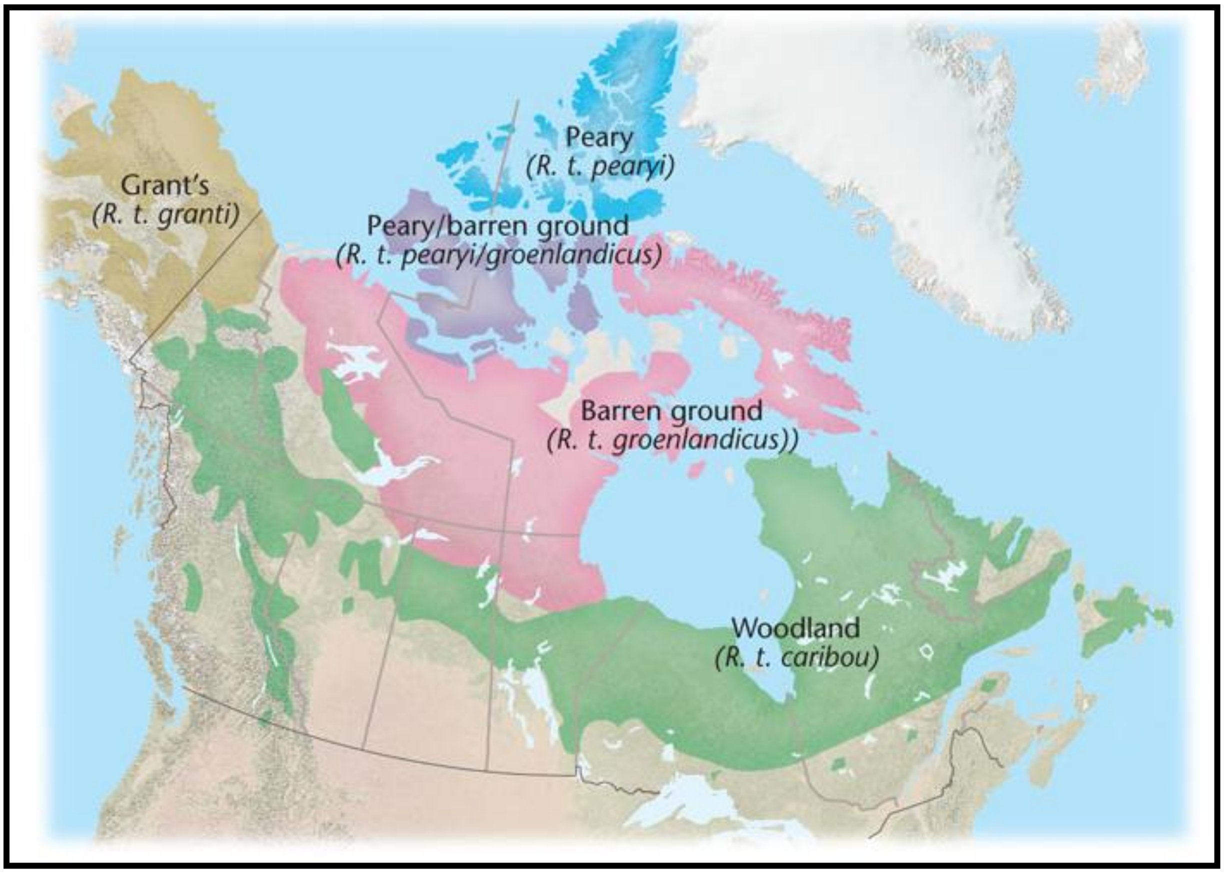


FIGURE 3. “Nationally Significant Populations” (predecessor of Designatable Unit) of caribou arising from COSEWIC status assessments (2000, 2002, and 2004).

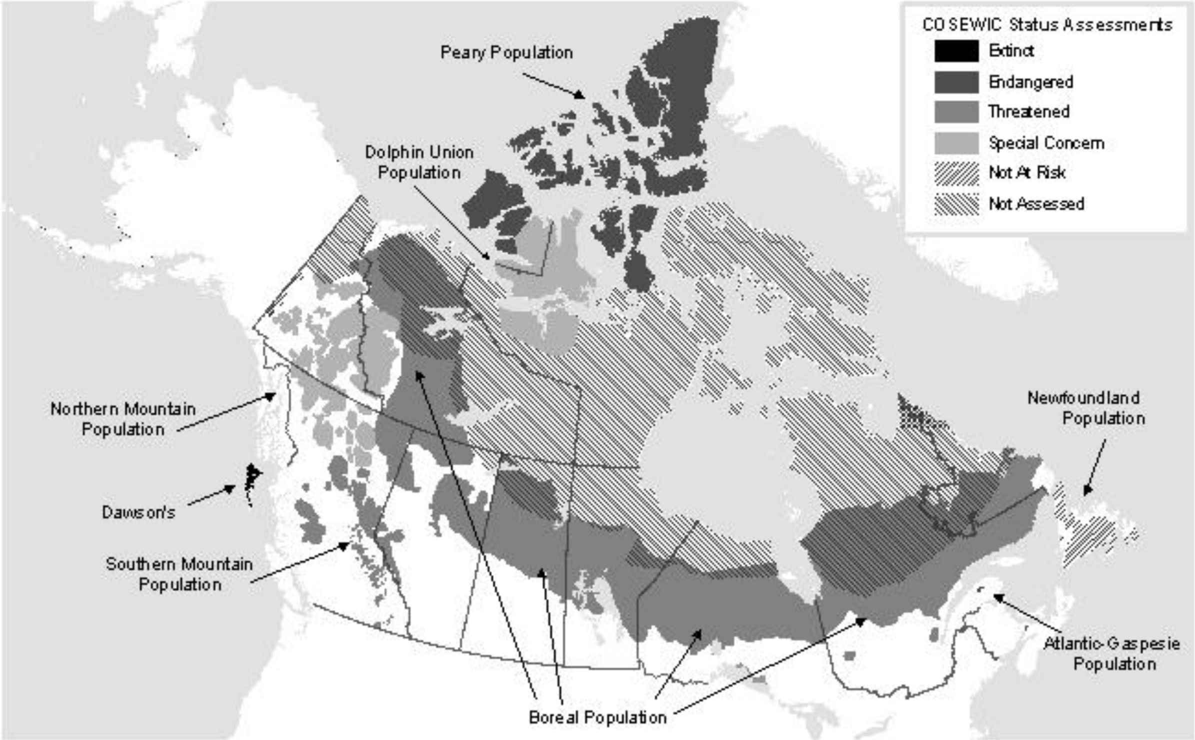
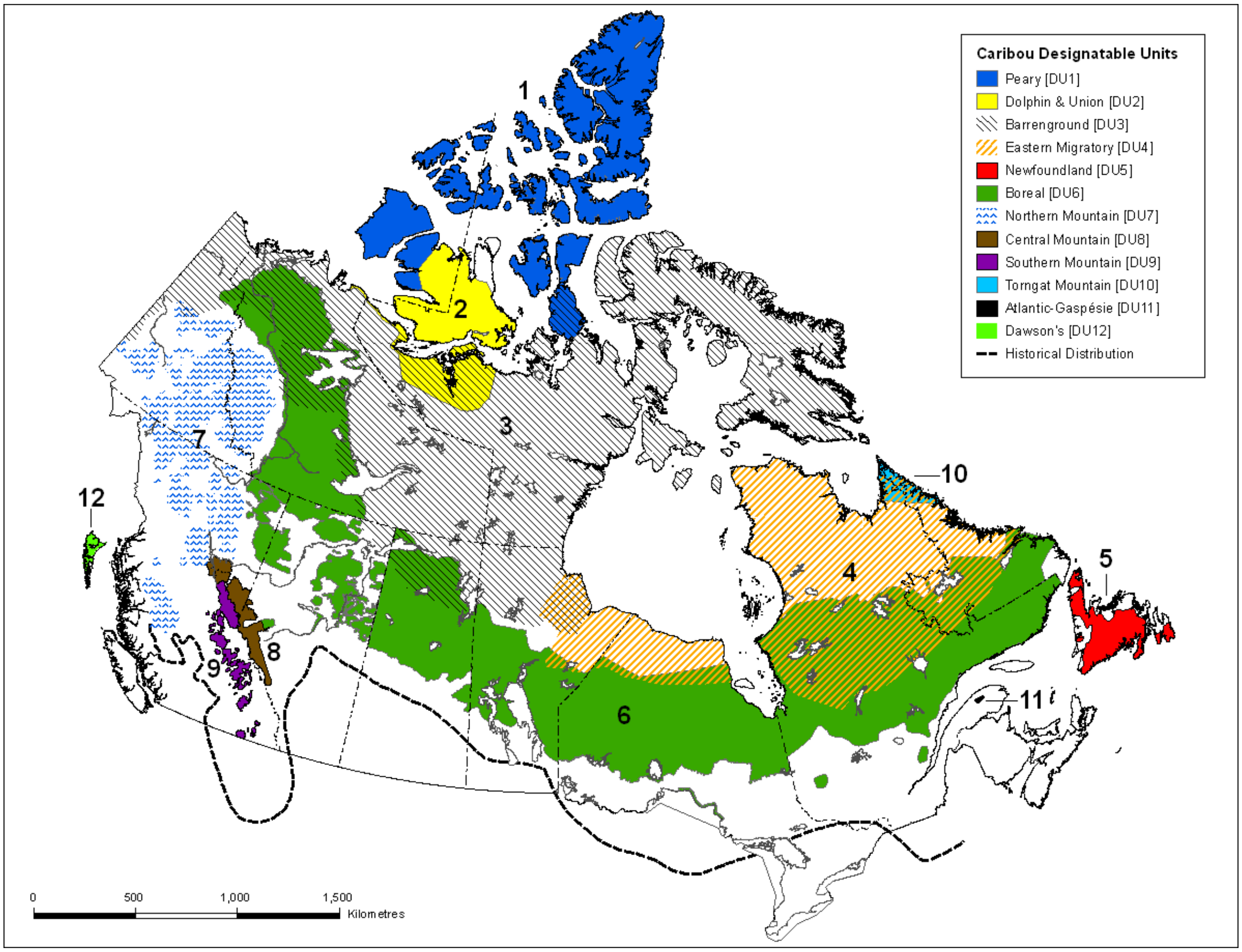


FIGURE 4. Designatable Units for Caribou (*Rangifer tarandus*) in Canada.



APPENDIX 1: Known Caribou populations (herds), or caribou conservation or management units in Canada and assigned Designatable Unit. Note: this does not include caribou in continuous ranges or areas with no known population structure (e.g., northern Ontario and Québec).

Recognized Herd/Population Name	**Jurisdiction(s)**	**D.U. Assignment**
Minto Inlet	NWT	Peary (DU1)
Banks Island	NWT	Peary (DU1)
Western Queen Elizabeth	NU	Peary (DU1)
Eastern Queen Elizabeth	NU	Peary (DU1)
Prince of Wales-Somerset-Boothia	NU	Peary (DU1)
Dolphin and Union	NWT/NU	Dolphin and Union (DU2)
Porcupine	YT/NWT*	Barren-ground (DU3)
Tuktoyaktuk Peninsula	NWT	Barren-ground (DU3)
Cape Bathurst	NWT	Barren-ground (DU3)
Bluenose East	NWT/NU	Barren-ground (DU3)
Bluenose West	NWT/NU	Barren-ground (DU3)
Bathurst	NWT/NU/AB/SK	Barren-ground (DU3)
Beverly/Ahiak	NWT/NU/ AB/SK/MB	Barren-ground (DU3)
Qamanirjuaq	NWT/NU/SK/MB	Barren-ground (DU3)
Southampton	NU	Barren-ground (DU3)
Coats	NU	Barren-ground (DU3)
Wager Bay	NU	Barren-ground (DU3)
Lorillard	NWT/NU	Barren-ground (DU3)
North Melville Peninsula	NU	Barren-ground (DU3)
Boothia Peninsula	NU	Barren-ground (DU3)
North Baffin	NU	Barren-ground (DU3)
South Baffin	NU	Barren-ground (DU3)

Mansel Island	NU	Barren-ground (DU3)
Fortymile	YT*	Barren-ground (DU3)
Cape Churchill	MB	Eastern Migratory Woodland (D4)
Pen Island	MB/ON	Eastern Migratory Woodland (D4)
Leaf River (Rivière-aux-Feuilles)	QC	Eastern Migratory Woodland (D4)
George River (Rivière George)	QC	Eastern Migratory Woodland (D4)
Blow Me Down Mountains	NL	Newfoundland (DU5)
Grey Islands	NL	Newfoundland (DU5)
Fogo Island	NL	Newfoundland (DU5)
Burin Knee	NL	Newfoundland (DU5)
Burin Foot	NL	Newfoundland (DU5)
St. Anthony	NL	Newfoundland (DU5)
Northern Peninsula	NL	Newfoundland (DU5)
Adies Lake	NL	Newfoundland (DU5)
Hampden Downs	NL	Newfoundland (DU5)
Gaff Topsails	NL	Newfoundland (DU5)
Buchans	NL	Newfoundland (DU5)
Lapoile	NL	Newfoundland (DU5)
Grey River	NL	Newfoundland (DU5)
Pot Hill	NL	Newfoundland (DU5)
Mount Peyton	NL	Newfoundland (DU5)
Middle Ridge	NL	Newfoundland (DU5)
Merasheen Island	NL	Newfoundland (DU5)
Cape Shore	NL	Newfoundland (DU5)
Avalon Peninsula	NL	Newfoundland (DU5)
Maxhamish	BC/NWT	Boreal Woodland (DU6)
Calendar	BC/NWT	Boreal Woodland (DU6)

Snake-Sahtahneh	BC	Boreal Woodland (DU6)
Parker Core	BC	Boreal Woodland (DU6)
Prophet Core	BC	Boreal Woodland (DU6)
Chinchaga	BC/AB	Boreal Woodland (DU6)
Bistcho	NWT/AB	Boreal Woodland (DU6)
Yates	NWT/AB	Boreal Woodland (DU6)
South Slave/SE Dehcho	NWT	Boreal Woodland (DU6)
Dehcho (N/SW)	NWT	Boreal Woodland (DU6)
North Slave	NWT	Boreal Woodland (DU6)
Sahtu	NWT	Boreal Woodland (DU6)
Inuvialuit	NWT	Boreal Woodland (DU6)
Gwich'in	NWT/YT	Boreal Woodland (DU6)
Caribou Mountains	AB	Boreal Woodland (DU6)
Little Smokey	AB	Boreal Woodland (DU6)
Red Earth	AB	Boreal Woodland (DU6)
West Side Athabasca River	AB	Boreal Woodland (DU6)
East Side Athabasca River	AB	Boreal Woodland (DU6)
Richardson	AB	Boreal Woodland (DU6)
Cold Lake	AB	Boreal Woodland (DU6)
Nipisi	AB	Boreal Woodland (DU6)
Slave Lake	AB	Boreal Woodland (DU6)
Davy-Athabaska	SK	Boreal Woodland (DU6)
Clearwater	SK	Boreal Woodland (DU6)
Primrose-Cold Lake	SK	Boreal Woodland (DU6)
Highrock-Key	SK	Boreal Woodland (DU6)
Smoothstone-Wapawekka	SK	Boreal Woodland (DU6)
Steephill-Foster	SK	Boreal Woodland (DU6)
Suggi-Amisk-Kississing	SK	Boreal Woodland (DU6)

Pasquia-Bog	SK	Boreal Woodland (DU6)
MB Kississing	MB	Boreal Woodland (DU6)
Naosap	MB	Boreal Woodland (DU6)
Reed	MB	Boreal Woodland (DU6)
William Lake	MB	Boreal Woodland (DU6)
Wapisu	MB	Boreal Woodland (DU6)
The Bog	MB	Boreal Woodland (DU6)
Wabowden	MB	Boreal Woodland (DU6)
North Interlake	MB	Boreal Woodland (DU6)
Atikaki- Berens	MB	Boreal Woodland (DU6)
Owl Flintstone	MB	Boreal Woodland (DU6)
South Woodland Caribou Provincial Park	ON	Boreal Woodland (DU6)
Sydney-Owl Lake	ON/MB	Boreal Woodland (DU6)
Berens -Atikaki	ON/MB	Boreal Woodland (DU6)
Churchill	ON	Boreal Woodland (DU6)
Brightsand	ON	Boreal Woodland (DU6)
Nipigon	ON	Boreal Woodland (DU6)
Pagwachuan	ON	Boreal Woodland (DU6)
Kesagami-Quebec	ON/QC	Boreal Woodland (DU6)
Lake Superior Coast	ON	Boreal Woodland (DU6)
Michipicoten	ON	Boreal Woodland (DU6)
Slate Islands	ON	Boreal Woodland (DU6)
Val d’Or	QC	Boreal Woodland (DU6)
Charlevoix	QC	Boreal Woodland (DU6)
Pipmuacan	QC	Boreal Woodland (DU6)
Manouane	QC	Boreal Woodland (DU6)
Manicouagan	QC	Boreal Woodland (DU6)

Lac Joseph	NL	Boreal Woodland (DU6)
Red Wine Mountain	NL	Boreal Woodland (DU6)
Mealy Mountain	NL	Boreal Woodland (DU6)
Graham	BC	Northern Mountain (DU7)
Charlotte Alplands	BC	Northern Mountain (DU7)
Itcha-Ilgachuz	BC	Northern Mountain (DU7)
Rainbows	BC	Northern Mountain (DU7)
Tweedsmuir	BC	Northern Mountain (DU7)
Takla	BC	Northern Mountain (DU7)
Telkwa	BC	Northern Mountain (DU7)
Wolverine	BC	Northern Mountain (DU7)
Chase	BC	Northern Mountain (DU7)
Pink Mountain	BC	Northern Mountain (DU7)
Finlay	BC	Northern Mountain (DU7)
Tsenaglode	BC	Northern Mountain (DU7)
Swan Lake (Jennings)	BC/YT	Northern Mountain (DU7)
Muskwa	BC	Northern Mountain (DU7)
Gataga	BC	Northern Mountain (DU7)
Frog	BC	Northern Mountain (DU7)
Spatsizi	BC	Northern Mountain (DU7)
Edziza	BC	Northern Mountain (DU7)
Level-Kawdy	BC	Northern Mountain (DU7)
Rabbit	BC	Northern Mountain (DU7)
Horseranch	BC/YT	Northern Mountain (DU7)
Liard Plateau	BC/YT	Northern Mountain (DU7)
Carcross	BC/YT	Northern Mountain (DU7)
Atlin	BC/YT	Northern Mountain (DU7)
Little Rancheria	BC/YT	Northern Mountain (DU7)

Clear Creek	YT	Northern Mountain (DU7)
Ethel Lake	YT	Northern Mountain (DU7)
Finlayson	YT	Northern Mountain (DU7)
Hart River	YT	Northern Mountain (DU7)
Ibex	YT	Northern Mountain (DU7)
Klaza	YT	Northern Mountain (DU7)
Kluane	YT	Northern Mountain (DU7)
Laberge	YT	Northern Mountain (DU7)
Chisana	YT*	Northern Mountain (DU7)
Pelly	YT	Northern Mountain (DU7)
Moose Lake	YT	Northern Mountain (DU7)
Tatchun	YT	Northern Mountain (DU7)
Tay River	YT	Northern Mountain (DU7)
Wolf Lake	YT	Northern Mountain (DU7)
Aishihik	YT	Northern Mountain (DU7)
Bonnet Plume	YT/NWT	Northern Mountain (DU7)
South Nahanni	YT/NWT	Northern Mountain (DU7)
Redstone	YT/NWT	Northern Mountain (DU7)
Coal River	YT/NWT	Northern Mountain (DU7)
La Biche	YT/NWT	Northern Mountain (DU7)
Quintette	BC	Central Mountain (DU8)
Scott	BC	Central Mountain (DU8)
Moberly	BC	Central Mountain (DU8)
Burnt Pine	BC	Central Mountain (DU8)
Kennedy Siding	BC	Central Mountain (DU8)
Narraway	BC/AB	Central Mountain (DU8)
Redrock/Prairie Creek	AB	Central Mountain (DU8)

A la Peche	AB	Central Mountain (DU8)
Jasper	AB	Central Mountain (DU8)
Bearhole/ Redwillow	BC/AB	Central Mountain (DU8)
Hart Ranges	BC	Southern Mountain (DU9)
Narrow Lake	BC	Southern Mountain (DU9)
North Cariboo	BC	Southern Mountain (DU9)
Barkerville	BC	Southern Mountain (DU9)
Wells Gray	BC	Southern Mountain (DU9)
Groundhog	BC	Southern Mountain (DU9)
Central Rockies	BC	Southern Mountain (DU9)
Columbia North	BC	Southern Mountain (DU9)
Columbia South	BC	Southern Mountain (DU9)
Frisby-Bolder	BC	Southern Mountain (DU9)
Monashee	BC	Southern Mountain (DU9)
Nakusp	BC	Southern Mountain (DU9)
Duncan	BC	Southern Mountain (DU9)
Purcells South	BC	Southern Mountain (DU9)
South Selkirks	BC*	Southern Mountain (DU9)
Torngat Mountains	NL	Torngat Mountains (DU10)
Gaspésie	QC	Gaspésie (DU11)
Dawson’s	BC	Dawson’s (DU12)

*Transboundary (with US) populations