Known Breeding Distribution and Abundance of Golden Eagles in Eastern North America

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Abstract - *Aquila chrysaetos* (Golden Eagle) breeds in both eastern and western North America. However, the former population has received much less attention than the latter. The purpose of this paper is to document the known distribution and abundance of eastern Golden Eagles within their breeding range and to identify gaps in knowledge for future studies. Eastern Golden Eagles breed in Labrador, Québec, and Ontario, Canada. The species has been extirpated as a breeder from the eastern US. In 2013, 187 Golden Eagle territorial pairs were documented in eastern Canada. Most territorial pairs occur in Québec (65.8%) and Labrador (26.7%). However, probably less than 16% of the total area of these regions has been surveyed. Based on the number of pairs observed and the proportion of area surveyed, we estimate that the total number of territorial pairs of eastern Golden Eagles to be ~1236. The large area of unsurveyed landscapes and the corresponding lack of precision of the estimate highlight an important next step for future research.

Introduction

Aquila chrysaetos L. (Golden Eagle) has a circumpolar distribution across the Palearctic and Nearctic, covering much of the northern hemispheres and extending south to northern Africa and central Mexico (Watson 2010). Only 1 of the 6 known subspecies of Golden Eagle inhabits North America. Two populations of Golden Eagles are recognized in Canada, the US, and Mexico—one in the west and one in the east (Katzner et al. 2012). Although western Golden Eagles have been extensively studied, eastern Golden Eagles are less abundant and less is known about them (Kochert et al. 2002). Individuals in the eastern population breed in Labrador, Québec, and Ontario. In autumn, they migrate through the Appalachian Mountain corridor and the Great Lakes, and the majority of them winter in the Appalachians, from Maine to Alabama. A few also winter in upper Midwestern states (i.e.,

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Michigan, Indiana, and Ohio) and in southern Québec (Brodeur et al. 1996, Katzner et al. 2012).

The eastern population of Golden Eagles is of increasing concern to conservationists and managers range-wide due to its small size, its vulnerability to a suite of human threats (e.g., wind-energy issues, trapping bycatch, lead poisoning) and the general lack of knowledge about these birds (Katzner et al. 2012). One of the main reasons for the lack of information on eastern Golden Eagles is the immense size and remoteness of the provinces in which they breed. Because these sites are so difficult to access and survey, biological data on breeding distribution of this species are difficult and expensive to gather. Furthermore, in the few cases where data are collected, studies are usually for specific environmental assessments and thus only locally focused.

Although nesting abundance is key information for monitoring, management, and conservation of bird species, to date, no attempt has been made to synthesize this information for the eastern Golden Eagle. This gap in knowledge is important because, in spite of the remoteness of the breeding sites, Golden Eagles have been documented by a substantial number of environmental assessments and a few large-scale surveys, suggesting that the population may be larger than current estimates. Here, we compile data on the known distribution and abundance of territorial pairs of this population throughout the species' range based on published and unpublished information, and we discuss key concerns on which future studies should focus.

Methods

Terminology

There are inconsistencies in the use of terminology describing breeding by raptors. In this study, we use the term territorial pair to describe a pair of eagles using a nesting territory, regardless of whether or not they were observed to breed. We defined a nesting territory as an area that contained 1 or more nests, including alternate ones, presently or historically used by a single pair (Steenhof and Newton 2007), and considered a nesting territory as occupied if a territorial pair was observed during any of the last 1, 2, or 3 visits because not all nests were visited more than once. Most of the nesting territories we report on were visited in the last decade. Golden Eagles usually reuse nesting territories for a long period of time (Kochert and Steenhof 2012). Evidence we counted as observations of a territorial pair included observation of either 2 Golden Eagles, an incubating bird, eggs or chicks in the nest, signs of refurbishment of a nest, or greenery (Morneau et al. 2012). We classified a nesting territory as abandoned if no evidence of a territorial pair was found despite at least 3 yearly surveys. Finally, we categorized a nesting territory as undetermined occupancy if it was visited fewer than 3 times without evidence of a territorial pair, or if it was occupied >20 years ago and has not been visited since that time.

Data collection and management

We collected data from peer-reviewed journal articles, unreviewed published information (grey literature), and unpublished data, including the Québec database

on bird species at risk (SOS-POP 2013). Some of these surveys were conducted by the authors (F. Morneau, T. Chubbs, C. Maisonneuve, and J.A. Tremblay).

The field data we considered, whether published or unpublished, were primarily from helicopter surveys of cliffs (e.g., Morneau et al. 2012). Other data came from spot-check surveys, which were single visits to potential nest sites that occurred as a by-product of aerial surveys not for Golden Eagles (e.g., waterfowl surveys or natural resource inventories), or aerial transportation. A few nests were also found during ground surveys.

For Québec and Labrador, where more data were available, we estimated the proportion of the area of the province that was surveyed and calculated the density of Golden Eagle nests per unit area (km^2). We then estimated the number of territorial pairs in the province by extrapolating that density over the total area of the region. Our understanding of Golden Eagle density and distribution in Ontario is so poor that we felt similar extrapolation there would be inappropriate.

Results

Golden Eagles nest in half of eastern Canada's provinces. We summarize our findings by presenting data in a spatially organized manner, from east to west.

Labrador and Newfoundland

Golden Eagles are observed in insular Newfoundland but are not known to breed there. Golden Eagles have been observed in Labrador since the Moravians (a Slavic ethnic group) settled the region in 1771 (Townsend and Allen 1907). At present, the province supports 50 known and occupied Golden Eagle nesting territories, most of which are located in the province's central river valleys (Fig. 1). Most of these birds were discovered in the 1980s and 1990s as a result of surveys conducted during environmental impact assessments for the Canadian Department of National Defense (DND 1994) and during the Voisey's Bay Nickel Mine impact assessment studies (VBNC 1997).

About 15% of Labrador's 269,073 km^2 has been surveyed. If the unsurveyed areas support similar numbers of Golden Eagles as do the surveyed areas, we estimate that the whole region could harbor 333 territorial pairs (50 Golden Eagles / 0.15 of total area).

Québec

Although the breeding status of Golden Eagles seems to be better known in Québec than in any other eastern province, there are few published records of Golden Eagles breeding there. The oldest substantiated record in the literature is from 1915, at Matane Lake in the Gaspé Peninsula (Baillie 1955); this territory was still occupied in 2013 (Ministère des Forêts, de la Faune et des Parcs [MFFP], QC, unpubl. data). Todd (1963) documented 2 adults that he observed at the mouth of the Petite Rivière de la Baleine (Hudson Bay drainage basin) in 1926. Spofford (1959) reported a nest with 2 adult Golden Eagles found at Sugluk Inlet (now Salluit) on the Ungava Peninsula in 1952. Between 1970 and 1989, a dozen new

occupied nesting territories were found, mostly on the Ungava Peninsula (Brodeur and Morneau 1999).

The vast majority of the >260 nests and 123 occupied territories in Québec (Table 1) have been discovered since 1990 during environmental impact studies for hydro-electric (Morneau et al. 1994, 2012), mining, road, or other development projects (SOS-POP 2013). Additional sources of nest data include bird atlases (Atlas des oiseaux nicheurs du Québec 2013, Gauthier and Aubry 1996), dedicated

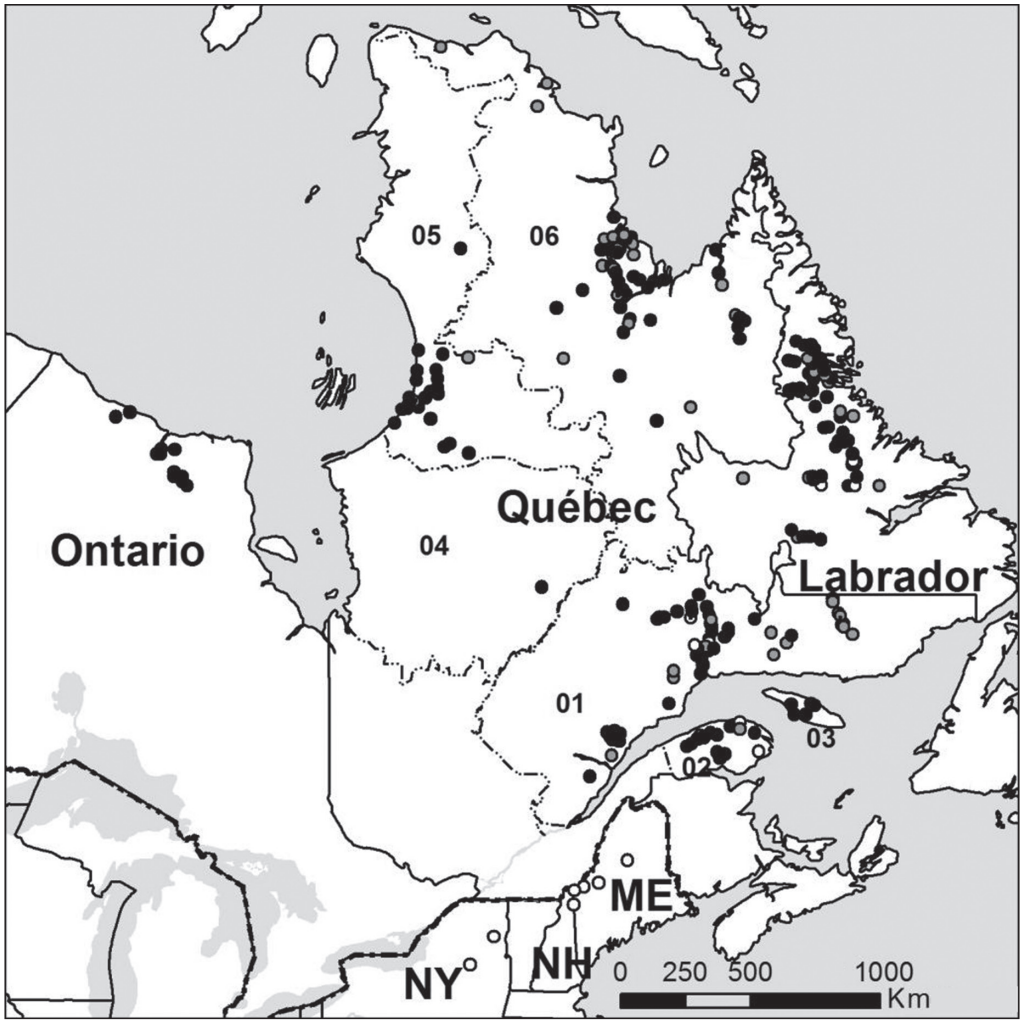

Figure 1. Golden Eagle nesting territories in eastern North America. Black dots represent occupied territory, white dots represent abandoned territory, and a grey dot represents an undetermined territory (see text for definitions of territory status). The province of Québec was divided into 6 regions: 1) north coast of the St. Lawrence River, 2) the Gaspé Peninsula, 3) Anticosti Island, 4) the James Bay drainage basin, 5) the Hudson Bay drainage basin, and 6) the Ungava Bay drainage basin. Golden Eagles are not known to breed in the un-numbered regions of south-central and southwestern Québec. Not all occupied nesting territories are shown on the map for Québec.

Golden Eagle surveys (McNicoll et al. 1996), and natural history observations (SOS-POP 2013).

Golden Eagles occur throughout 6 very distinct regions of Québec. These include 1) the north coast of the St. Lawrence River, 2) the Gaspé Peninsula, 3) Anticosti Island, 4) the James Bay drainage basin, 5) the Hudson Bay drainage basin, and 6) the Ungava Bay drainage basin (Fig. 1). Golden Eagles are not known to breed in south-central and southwestern Québec, and we do not discuss those regions here. We describe each of the regions with Golden Eagles below.

North coast of the St. Lawrence River (north of Québec City; 01 in Fig. 1). The topography of this region is hilly to mountainous, and elevations extend from sea level to 1100 m. Vegetation is mostly forested with some open areas (alpine tundra, burns, heath, and clear-cuts). Cliffs (nesting habitat for Golden Eagles) are relatively common and well distributed. There are few roads, but there is significant logging activity in the south.

The limited surveys that have been conducted in this area occurred from helicopters and mostly in the last decade. In these surveys, the main stem of about 25% of the ~36 large river valleys in the region were checked for cliff nests, and 36 territories region-wide were documented as occupied, 15 others of undetermined status were found, and 3 were documented as abandoned (Table 1; SOS-POP 2013). Less than 25% of the 257,646 km^2 in the area has been surveyed; however, if known density estimates are consistent region-wide, then we estimate that the region supports 144 territorial pairs (36 / 0.25).

Gaspé Peninsula (02 in Fig. 1). The Gaspé Peninsula is mostly mountainous, with elevations ranging from sea level to 1268 m (Mount Jacques-Cartier). The landscape is dominated by boreal deciduous and coniferous forests, although some of the summits are open alpine tundra and the forests have been heavily logged. Cliff-nesting habitat is relatively common.

There are 15 documented Golden Eagle nesting territories on the Gaspé Peninsula (SOS-POP 2013). In 2013, 11 territories were occupied, whereas the others were abandoned or of undetermined status (Table 1). Most of these territories are concentrated in the northern, more mountainous part, of the Peninsula (Fig. 1).

Table 1. Abundance of known Golden Eagle nesting territories in 6 regions of Québec in 2013. Undet. = nesting territories for which status could not be determined.

	Area (km^2)		Known number of nesting territories			
Region	Surveyed	Not surveyed	Occupied	Undet.	Abandoned	Total
North coast of the St. Lawrence River (north of Québec City)	64,412	193,235	36	15	3	54
Gaspé Peninsula	15,538	15,538	11	2	2	15
Anticosti Island	789	7103	5	0	0	5
James Bay drainage basin	16,200	333,800	2	0	0	2
Hudson Bay drainage basin	27,000	173,000	22	2	0	24
Ungava Bay drainage basin	38,000	346,097	47	23	0	70
Total	161,939	1,068,773	123	42	5	170

The Gaspé Peninsula covers an area of 31,075 km^2. Because most nests have been found through spot checks, it is difficult to precisely assess previous sampling effort. However, we estimate that approximately 50% of the area has been effectively surveyed and thus the region may support about 22 pairs of Golden Eagles (11 / 0.50).

Anticosti Island (03 in Fig. 1). Anticosti Island is located in the Gulf of St. Lawrence, northeast of the Gaspé Peninsula but east of the mainland. The island is hilly and forested, but open bogs and clearcuts are abundant. Cliffs are locally common along river valleys and on the north side of the island.

From 2010 to 2013, surveyors collecting data for a bird atlas found 5 occupied Golden Eagle nesting territories on cliffs in river valleys near the center of the island (Atlas des oiseaux nicheurs du Québec 2013; Fig. 1). Some of these newly found nests are huge, suggesting that they have been used for many years. No more than 10% of the island's 7892 km^2 has been surveyed, and thus, Anticosti Island may support about 50 territorial pairs of Golden Eagles (5 / 0.10).

James Bay drainage basin (04 in Fig. 1). The western third of the James Bay drainage basin is relatively flat, with large bogs and very few cliffs. The middle third of the drainage basin is rolling land with scattered hills sometimes bisected by small cliffs. The eastern third has many cliffs and is hillier; the Otish Mountains extend to nearly 1000 m in elevation. All 3 landforms are dominated by open biotopes driven by the short, 50-y regional fire cycles (Héon 2010).

Only 1200 km^2 of this region (<1% of its 350,000 km^2) has been surveyed for Golden Eagles and a few sites have been spot-checked (Benoit and Ibarzabal 2004). One occupied territory was found in the Otish Mountains and 2 adults were observed near a cliff in the northeast, along the La Grande Rivière (Fig. 1). If cliffs observed during waterfowl surveys are included (about 15,000 km^2 of surveys), then an estimated 5% of the James Bay drainage basin has been surveyed for Golden Eagles, and we estimate that the region may support about 40 pairs of territorial Golden Eagles (2 / 0.05).

Hudson Bay drainage basin (05 in Fig. 1). The topography of this region varies from coastal cuestas and gentle hills to a lake plateau in the southeast. Cliffs are common, especially in the southwest. Landcover is primarily tundra and forest tundra; even in the taiga, in the south, landscapes are largely open due to the relatively short fire-return interval.

Between 1990 and 1992, a 10,600-km^2 area in the southwest of the region was completely surveyed for Golden Eagle nests (Morneau et al. 1994). In the same period, an adjacent area of 10,000 km^2 was partly checked for Golden Eagle nests (Morneau et al. 1994). The lead author incidentally checked an additional 6400 km^2 in association with other work. In total, 22 occupied territories and 2 territories of unknown status were found during these surveys (Table 1). The drainage basin covers 200,000 km^2; thus, approximately 86% is unsurveyed and the area may support about 157 pairs (22 / 0.14).

Ungava Bay drainage basin (06 in Fig. 1). Local topography in this northernmost region of Québec varies from coastal plains and hills near the tips of Ungava

Peninsula and in the south, to mountains in the east, including mount D'Iberville; at 1622 m, it is the highest point in Québec. Cliffs are well distributed throughout the region, especially in river valleys. This region is predominantly covered by tundra and forest tundra.

An area of approximately 25,000 km^2 near Kuujjuaq has been partly searched for Golden Eagle nests as were smaller areas near Deception Bay at the tip of Ungava Peninsula (MFFP, unpubl. data), south of Kuujjuaq, along the west coast of Ungava Bay and Ungava Peninsula, and in part of the George River, Caniaspicau River, and Korok River valleys. These surveys revealed that the region supports the greatest known abundance of Golden Eagles in the province. There are 47 described occupied Golden Eagle nesting territories in the region and 23 of undetermined status (Table 1). All of the nests found are located on cliffs.

Overall, less than 38,000 km^2, or 10% of the region's 384,097 km^2, has been surveyed for Golden Eagles. Extrapolating to the remaining 90%, we estimate that the region may support about 470 pairs (47 / 0.10). Furthermore, recent telemetry data suggest that this region may also support large numbers of summering non-territorial and non-breeding Golden Eagles (Miller 2012).

Ontario

The first Golden Eagles documented to breed in Ontario were observed in the southwest region of Kenora in 1959 (Peck and James 1983). All more recently documented evidence of nesting has occurred on the opposite side of the province in the Hudson Bay Lowlands (Fig. 1; Bird Studies Canada et al. 2008). There is no evidence that the species may still nest in the southwest of the province (Sutherland 2010).

In aerial surveys conducted during 2001–2003, fourteen occupied territories were found in the Sutton Ridges and along the major rivers draining the northern Hudson Bay Lowlands (Sutherland 2010). The size of the provincial breeding subpopulation remains unknown, but given the relatively small proportion of the province surveyed, it likely comprises at least 20 territorial pairs (Sutherland 2010).

Summary for eastern Canada

There are 187 known territorial pairs of Golden Eagles in eastern Canada (Table 2). Most inhabit Québec (65.8 %) and Labrador (26.7 %). However, over 84% of the vast area of Canada's eastern provinces has never been surveyed for Golden Eagles. By summing all the previous estimates, it might be approximated that eastern Canada may currently support ~1236 territorial pairs.

Northeastern US

At present, Golden Eagles no longer breed in the northeastern US. Reputable historic accounts of Golden Eagle nesting are reported from at least 5 states in this region (Table 3; Katzner et al. 2012). In 1736, in Maine, early European settlers described a Golden Eagle nest based on Abenaki (Native American/First Nations) lore. Another cliff nest in Piscataquis County, ME, was sketched and labelled in 1689. The Abenakis had traditionally named both sites Sowangan-adjoo translated

as Eagle Mountain (Eckstrom 1936, Palmer 1988). These are among the earliest written accounts of Golden Eagle nesting in eastern North America.

Most of the nests known in the eastern US were in the Appalachian corridor, although some were recorded in New York's Adirondack Mountains. Since 1960, occupancy by Golden Eagles has been documented in only 8 territories, all in states bordering Canada (Table 3, Fig. 1; Spofford 1971, Todd 2000). The last breeding activity (1996), pair occupancy (1997), and territorial adult (1999) were all documented in northern Maine at the same cliff nest first described in 1736.

Together, these data suggest that the northeastern US was historically at the edge of the Golden Eagle's breeding distribution. Birds were likely at chronically low breeding density, and have exhibited a prolonged northward retreat in breeding range since European arrival in North America. There is no sound historical evidence that naturally occurring Golden Eagles bred in the Appalachians south of New York (Lee 1990). Some recently translocated (Katzner et al. 2012) birds may,

Table 2. Number of Golden Eagle nesting territories in eastern North America in 2013. Population estimate for Ontario is from Sutherland (2010); all others from this study.

	Number of known nesting territories				% area	Population
Region	Occupied	Undetermined	Abandoned	Total	surveyed	estimate
Ontario	14	0	0	14	?	20
Québec	123	42	5	170	15	883
Labrador	50	12	6	68	15	333
Eastern US	0	0	8	8	-	0
Total	187	54	16	257	15	1236

Table 3. Earliest and most recent of Golden Eagle nesting territories in eastern North America, by state and province. The species has been extirpated from the US as a breeder; historical numbers are provided for US states where Golden Eagles once bred. Newfoundland is excluded, as there are no records of birds breeding there.

	Golden Eagle nesting territories		Documented territory occupancy	
Region	# since 1962	Historic total #	Most recent	Earliest
Canadian province				
Labrador	-	-	Present	--
Québec	-	-	Present	1915
Ontario	-	-	Present	1959
US state				
Maine	4	11	1997	1680s
Massachusetts	0	1	1880s	1880s
New Hampshire	1	3	1961	1830s
New York	3	8	1979	1770s
Pennsylvania	0	1	1850s	1850s
Vermont	0	1	1900s	1890s

however, have bred in Tennessee (a recently fledged juvenile Golden Eagle was brought to a TN rehabilitation facility in summer 2012).

Discussion

The review we present here is a first attempt to describe the distribution and abundance of Golden Eagles across their range in eastern Canada and the northeastern US. Our work also highlights a number of knowledge gaps regarding this population and provides a context for future research and conservation actions.

Golden Eagles are broadly distributed across northeastern Canada. The majority of this population breeds in Québec, but there are also breeders in Labrador and Ontario. Although we document here the presence of 187 known territorial pairs, >84% of this vast region has never been surveyed for Golden Eagles, and we estimated that the number of breeding pairs is ~1236. A typical stable age structure for Golden Eagles predicts that the breeding population is comprised of ~50% of the population (e.g., Katzner et al. 2007). If this population is stable, then we estimate that the population includes ~5000 individuals (1236 adult territory-holding males + 1236 adult territory-holding females = 2472 adults + 2472 pre-adults = 4944 birds).

There are knowledge gaps in our description of Golden Eagle distribution and abundance, and they pertain to areas that have been surveyed for Golden Eagles and to unsurveyed areas. In the surveyed areas, the actual number of territorial pairs is probably greater than we report here. Indeed, Golden Eagle nests are not trivial to find, and it generally takes at least 2 years of surveys to identify all of the nesting territories and territorial pairs in an area (McIntyre and Adams 1999, Morneau et al. 2012, Phillips and Beske 1990). However, most areas were surveyed in only 1 year. Furthermore, only spot-checks were conducted in numerous areas.

It is also probable that a number of the territories with indeterminate status are in fact occupied. Indeed, in most cases, only 1 nest is known in each of those territories. However, in 1 particularly well-studied region along the north coast of the St. Lawrence River, there were, on average, 3.3 nests per territory (n = 20 territories; Morneau et al. 2012). Such a pattern is not unique to Canada, and other studies generally report more than 1, and up to 18 nests in a nesting territory (Kochert and Steenhof 2012, Kochert et al. 2002). Thus, where the status of a territory is unknown, it may be that the nest that was found is one that is rarely used. In such a case, it may be likely that some other more regularly used nest exists and the territory is occupied in spite of the fact that birds are almost never seen at the only known nest (Milsap et al. 2014).

Within unsurveyed regions, there are 2 key areas in which future work could enhance present understanding of Golden Eagle distribution and abundance: (1) better demarcation of the breeding range of the species in eastern Canada and (2) improved characterization of Golden Eagle habitat associations. The extent of the documented Golden Eagle breeding range continues to expand. In Manitoba, 6 Golden Eagle nesting territories were recently found in the Hudson Bay lowlands of Wapusk National Park (Asselin et al. 2013). It is not clear if these are actually nests of western birds, if this finding represents a recent range expansion by eastern birds,

or if the new data represent a more clear understanding of the actual extent of the breeding distribution of this species. Nevertheless, Golden Eagles tend to be cryptic and difficult to find during the breeding season. It therefore may be that there are Golden Eagles breeding at low densities in a greater area of eastern Canada than is presently recognized, including in some of the areas south of the known range of the species in Ontario and Québec.

Golden Eagle habitat use in eastern Canada is also not well understood. Golden Eagles are thought to be primarily found in mountainous terrain (Watson 2010). However, the Golden Eagles reported in Manitoba were breeding in a similar low-relief habitat as those found in northern Ontario. Likewise, in eastern Canada there are records of Golden Eagles nesting in trees of the Hudson Bay lowlands and on a flat plateau of the Gaspé Peninsula. Finally, although the species is associated with open habitats, it can be found in clear-cuts within forest matrices or even in relatively closed landscapes (SOS-POP 2013). Thus, while broad principles of Golden Eagle ecology can be applied to understanding the species' distribution, more robust estimates of population size could be generated with region-specific nesting-habitat suitability models. The number of Golden Eagles we estimated, ~1236 territorial pairs (~5000 individuals), appears relatively low for an area as large as eastern Canada. The lack of knowledge about the true habitat associations and breeding distribution underlines the importance of both future conservation action for the species and additional research to underpin those actions.

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