Aerial survey of moose in hunting zone 17 in winter 2021

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Collaboration

Cree Nation Government, Cree First Nation of Waswanipi and Cree Trappers' Association

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The Cree First Nation of Waswanipi was particularly involved in logistics, specifically in management of snow removal on forest roads and then ensuring development of fuel reserves. The community of Waswanipi also assumed responsibility for accommodation and subsistence of a full crew. Steven Blacksmith and his team thus deployed a functional isolated base of operations north of the study area. This contribution was essential to the completion of the work, due to health restrictions related to the COVID-19 pandemic, which obliged the creation of a crew isolated from the community. Acknowledgments are given to Serena Snowboy for coordination of the CFNW contribution.

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EXECUTIVE SUMMARY

An aerial survey of moose in hunting zone 17 was conducted in winter 2021 according to the recommendation of the Hunting, Fishing and Trapping Coordinating Committee (HFTCC). Concerns regarding the population trend were based on a considerable decline in non-Native hunting success and the Cree tallymen's concerns. This project arises from a financial and logistical collaboration of the Ministère des Forêts, de la Faune et des Parcs, the Cree Nation Government, the Cree First Nation of Waswanipi and the Cree Trappers' Association (CTA).

The survey showed a 35% reduction in the abundance of moose since 2009. The number of moose in zone 17 was estimated at 1,036 (±16%; α = 0.1). The absence of moose in several parcels of the low and high strata partly explains the decrease in density, estimated at 0.52 moose/10 km^2. The regeneration of the forest cutovers is at the origin of a large proportion of moose forest habitats in zone 17. However, the proportion of mixed and hardwood forest stands is decreasing. Nonetheless, the availability of quality habitats for moose would not be a cause of the population reduction.

There were about 180 males in the entire zone at the time of the survey, representing a ratio of 27.3 ±7.6 males/100 females, the lowest ratio surveyed to date. The decrease in the proportion of males among the adults would result from selective hunting, which would have targeted males in a proportion of 78% since 1996. In response, the growth of the proportion of female had increased this population's resilience. However, the pressure of selective hunting had become unsustainable. The moose harvest potential is reduced due to the necessity of protecting females.

The low proportion of 30 calves/100 females — estimated before spring mortality — indicates a recruitment problem in zone 17. Recruitment was 27 calves/100 females in the high stratum, an observation lower than the average for the entire zone, although it offers a better-quality habitat for moose. Considering that the moose gestation rate is normal, it is likely that predation is involved, particularly by black bears, an omnivorous species that also benefits from vegetation in habitats favourable to moose.

The 29% decrease in the number of females and the 40% decrease in the number of males since 2009 would be difficult to explain by predation. This finding results from a reversal of the average annual population trend, from about +8% from 2003 to 2009, to -4% from 2009 to 2021. It is very unlikely that the wolf population grew sufficiently to induce this decline in the ecological context of the past decade. It is more likely that the increase in the adult mortality rate is the result of overharvesting.

Modelling of the mortality rate by hunting provides an improbably sustainable estimate of 14% per year since 2009. The non-Native harvest rate averaged 5.7% per year, a value analogous to the one measured during population growth. Inadequate monitoring of Indigenous harvesting would underestimate its effect on the moose population. Speculation on the causes of mortality limits the interpretation of the proportions attributable to hunting and predation.

Wildlife management of zone 17 has been supervised by the Hunting, Fishing and Trapping Coordinating Committee for over 40 years. It has been the subject of many surveys and expert opinions showing that hunting would be the main factor limiting the number of moose. The results presented in this report support this finding. The ecosystem of zone 17 would still be favourable to growing moose numbers in a context of sustainable hunting management.

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CTA	Cree Trappers' Association
JBNQA	James Bay and Northern Québec Agreement
HFTCC	Hunting, Fishing and Trapping Coordinating Committee
CCFB	Cree-Québec Forestry Board
CNG	Cree Nation Government
MFFP	Ministère des Forêts, de la Faune et des Parcs
CFNW	Cree First Nation of Waswanipi

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INTRODUCTION

An aerial survey was conducted in winter 2021 in hunting zone 17, estimating the number of moose (*Alces alces*) at 1,036 (±16%; α = 0.1). This result shows a 35% decrease since 2009 in a zone where the moose density is among in the lowest in the province. The comparison of the results of the six annual surveys conducted in zone 17 since 1985 shows great variability in the number of moose in this territory (Figure 1). The management of this zone is currently faced with the second considerable reduction of the moose population in its recent history.

In 1975, zone K3 retained its delimitation and became zone 17 due to the signing of the James Bay and Northern Québec Agreement (JBNQA). This agreement also refers to zone 17 as a “buffer area” in which the Cree Nation benefits from the “right to harvest” (s. 24.3.1) and a “priority of Native harvesting” (s. 24.6) over non-Natives. The moose hunt is managed in this zone under the *Act respecting hunting and fishing rights in the James Bay and New Québec territories* (D-13.1). The Hunting, Fishing and Trapping Coordinating Committee administers this special hunting regime, in particular, by issuing recommendations to the gouvernement du Québec. It also has the power to establish the upper limit of kill for moose for Native people and non-Natives (s. 24.4.30). The results of the aerial surveys are at the core of the regulatory process, because they provide a detailed profile of the demography of the moose population, used to calculate and allocate the harvest potential.

Zone 17 is located in the spruce-moss bioclimatic domain. In this type of habitat, low food diversity and density would be the main natural factor regulating the moose populations (Courtois et al., 1993). Death by predation and hunting are the limiting factors that add to the low productivity of the females. Despite its low density, moose is an animal of great importance in Nord-du-Québec. In zone 17, it constitutes a traditional food input in the Cree communities of Waswanipi and Oujé-Bougoumou, some of whose traplines cover the vast majority of the zone. The Indigenous moose harvest in this zone is administered by the Cree tallymen. The moose hunt in this zone is also culturally significant for non-Natives who also frequent these traplines for hunting. Since the arrival of many non-Natives in the region during the years 1960 and 1970, their population decreased, and the number of non-Native hunters decreased from over 2,200 in the 1980s to about 850 since 2009. Management of moose hunting in zone 17 therefore integrates notions of the biology of the species, the “right to harvest” and sharing with non-Natives in respect of “priority of Native harvesting” and the provincial regulations.

In 1985, the first survey specific to zone 17 had estimated the number of moose at 1,140. Modelling of the survey results and harvest data suggested a harvest rate of 19% (Goudreault, 1985). This value appeared high, considering the maximum sustainable harvest rate, which then was estimated at 15%, and even 20% by Jolicœur (1977). However, this theoretical study recognized the little information available, especially for this zone, and was inspired by the first aerial surveys in the western spruce-moss forest (Grenier, 1974; Morasse, 1975) conducted in the north of zone 17. Goudreault (1985) had stated the hypothesis that the moose shortage in zone 17 was due to overharvesting, considering that the harvest surveys were incomplete and that, in the 1970s, poaching was a considerable cause of mortality (Jolicoeur, 1977). The decrease in hunting success per unit of effort suggested that the moose density would have been twice as high in the 1970s. This finding had turned out to be plausible with the continued acquisition of knowledge in zone 17.

In 1991, an aerial survey estimated the number of moose at 667 (0.29 moose/10 km^2) in zone 17 and indicated a 42% population decrease since 1985. In that period, the situation motivated the production of harvest potential analyses specific to this zone and recommendations on harvest restrictions in view of recovery of the moose population (Leblanc et al., 1993; Messier, 1993; Lapointe et al., 1994; Courtois and Lamontagne, 1995). The combination of harvest surveys of non-Natives and the Cree Trappers’ Association showed that the annual harvest rate was at least twice as high as the sustainable harvest rate. These analyses converged on the finding that overharvesting was causing the continued decrease in the number of moose. These authors indicated that the harvest rate reduction necessarily had to include protection of females to favour an increase in moose density.

The adoption of the provincial management plan (MLCP, 1993) introduced a rotational selective harvest, allowing killing of females one year out of two, a unique pilot project in the province. The rotation was to be applied elsewhere in the province in 1999, but without having been tested experimentally in zone 17. In 1995, the HFTCC intervened to accentuate this restriction and set a maximum limit of 140 moose kills for Natives and non-Natives. This limit was lower than the harvest level guaranteed to the Crees of 158 moose, below which the harvest can legally be exclusive to them (s. 24.6.3). During that period, the Crees had chosen to share 40 moose from their guaranteed level of harvest with non-Natives. To favour compliance with this sharing of the harvest, the non-Native hunting period was shortened from 23 to 16 days, and the harvest was limited to males. The CTA registered an average of one voluntary report of 104 moose from 1985 to 1991. Because this register was partial, the Cree tallymen concerned by zone 17 had to reduce the Native harvest on their traplines. The Cree hunters therefore were informed of the necessity of limiting their harvest, particularly of females, with the goal of favouring population growth potential and sharing of the resource with non-Natives. The HFTCC was going to review the relevance and observance of the maximum limit on kills on an annual basis, based on the evolution of the harvest and an aerial survey.

In 1996, an aerial survey showed an increase to 836 moose (Lapointe and Rivard, 1996). In five years, the moose density in zone 17 grew from 0.29 to 0.42 moose/10 km^2. This finding was accompanied by record recruitment for this zone of 70 calves/100 females. The harvest management conditions recently reviewed then seemed favourable to moose population growth. However, these positive results were nuanced by Messier (1996) who suggested caution in view of the confidence interval of the estimates and possible overestimation of recruitment. The management recommendations were unanimous that increased protection of females would be required to accelerate the achievement of a sustainable harvest rate that would exceed the guaranteed level of harvest. An independent analysis of various sex-based harvest scenarios then was produced by the Grand Council of the Crees of Québec (Messier, 1998). Among six scenarios tested, the harvest of 40 males by non-Natives and 100 moose by the Crees maintained population growth and slightly reduced the proportion of males. From 1996 to winter 2003, the HTFCC maintained the hunting conditions on an annual basis. Nonetheless, according to the CTA register, the harvest potential by Native hunters theoretically was not reached. During that period, the average non-Native annual harvest (± standard deviation) was 36 (±6) moose, Native voluntary reporting was 60 (±13) moose; and the minimum harvest totalled 96 (±18) moose. During that same period, however, the number of non-Native hunters decreased from 1,087 to 584 and, consequently, their hunting success increased from 3.5% to 7.2%. The moose population growth outlook was mitigated by the stagnation of the harvest and the disinterest of non-Native hunters.

The considerable decrease of the moose population in the 1980s and 1990s had also raised concerns regarding the effect of logging on habitat quality. The main themes invoked were that large-area cuts reduces the availability of food and forest cover, displace moose from traditionally used sectors, and favour access by hunters (Messier, 1993). Since then, the Agreement Concerning a New Relationship Between le Gouvernement du Québec and the Crees of Québec[6], also known as the Paix des braves, led to the adapted forest regime. This reform of forestry has been in effect since 2003 in zone 17. It arose from negotiations based on the will of the Crees to preserve and value their way of life and their traditional knowledge. The main motivation of this Agreement concerned the area of the cuts performed since the 1970s, which were considered too vast (250 to 500 ha). By prioritizing block cutting and several adaptations of the provincial forest regime, the area of the cuts has since been reduced, being from 50 to 150 ha, rarely exceeding 100 ha. Forest planning is also performed on the scale of the Cree traplines, respecting various disturbance thresholds and a consultation process with the tallymen. The main planning assistance tool for logging is a mapping of traditional knowledge and sites of importance. This mainly represents values of conservation of wildlife and their habitats. The maintenance of a quality habitat for moose is one of the main themes of this zoning and conservation objectives (Jacqmain et al., 2012). Currently, moose habitat quality is also one of the main issues of the Cree-Québec Forestry Board (CQFB, 2022), for which the results of the aerial surveys are of great interest.

[6] See chapter 3 of the *Act to ensure the implementation of the Agreement Concerning a New Relationship Between le Gouvernement du Québec and the Crees of Québec* (chapter M-35.1.2).

In winter 2003, an aerial survey estimated the number of moose at 1,033 (0.45 moose/10 km^2) in hunting zone 17. However, the growth thus measured since 1996 was nuanced by the overlapping confidence interval of these two estimates (St-Pierre et al., 2005). This demographic update indicated that the very high recruitment observed in 1996 was not maintained. The increase in hunting pressure on males translated into a reduction of the sex ratio to a value representative of a population for which the hunting effort seeks in part to protect females. This resulted in a 25% increase in the number of females in the zone, and their proportion was relatively high at 69.4%. In exchange, the proportion of males in the zone decreased to 30.6%, reaching the minimum threshold suggested in Québec to avoid compromising female productivity. According to this theory, the sex ratio measured in 2003 optimized the growth potential of moose numbers in this zone.

Over the subsequent years, the increase in hunting success and the number of moose harvested by non-Natives indicated an upward trend in the number of moose (Leblanc, 2007). The improvement of these management indicators occurred when the harvest conditions were unchanged. The HTFCC found that the limit on non-Native kills (40 males) had been exceeded since 2003 and reached 76 males in 2005. Over the next few years, the HTFCC stopped setting an upper limit of kills and engaged in a reassessment of the effectiveness and relevance of the harvest conditions applied since 1996. Tracking the progression of the demographic indicators was the subject of several meetings among the Gouvernement du Québec, the Cree Nation Government and the CTA in the context of a HTFCC working group. The growth of the harvest reached a peak for zone 17 during the 2007-2008 hunting season with the reporting of 203 moose kills, including 89 males killed by non-Natives (Figure 2). The relatively high non-Native hunting success was maintained despite the increase in the number of hunters from 2003 to 2007 (Figure 3). The HTFCC expressed the necessity for an aerial survey to confirm the moose population growth finding, based on the maintenance of hunting success in a harvest growth context.

In 2009, a survey confirmed an average moose population increase of about 8% annually since 2003, indicating a density of 0.78 moose/10 km^2 (Morin et al., 2009). Since the beginning of its monitoring, the moose population had peaked at 1,581. The protection of females over the previous 13 years was the main factor explaining this growth. Considering the reported harvest, this survey showed that annual moose productivity was comparable to that of zones with largely higher moose densities. The ratio of 34 males/100 females showed that the hunting pressure on males was optimized and sustainable in this context. The growth of the Native harvest was similar to that of the non-Native harvest. The consistency between these indicators had reduced the uncertainty about the value of the CTA register based on voluntary reporting of kills. The key management indicators thus showed their usefulness. Since the 1970s, the growing proportion of regenerating cut blocks, and of mixed and hardwood stands, led to a clear improvement in habitat quality in areas previously of low moose densities (Leblanc, 2007; Morin et al., 2009). The moose density measured in 2009 would have been analogous to that of the 1970s, the period when the habitat potential was theoretically lower. The outlook for continued moose population growth then was well-founded and, to achieve this, the non-Native hunting management measures were maintained.

The population increase confirmed in 2009 came at a time when the provincial moose management plan was being revised (Lefort and Massé [ed.], 2015). Modelling of various harvest scenarios had been undertaken at that time to validate the demographic predictions and establish the objectives presented in this plan for the 2012-2019 period. Since 1996, the protection of females and the reduction of the harvest rate favoured net annual growth of about 5% up to 2009. In a more recent perspective, the annual growth rate was about 10% from 2003 to 2009. During that period, the harvest rate would have varied from 10% to 16%, suggesting an intrinsic growth rate (before hunting) of about 22% annually (Morin et coll., 2009). Habitat quality improvement by forestry, combined with harvest management by selective hunting, favoured the population growth potential. For this high-growth period, the harvest reported by all hunters were composed, on the average, of 80% males[7] (standard deviation of 2%). Simulations evaluated various growth scenarios after hunting, varying from 5% to 10%. These simulations presumed a gradual growth of the selective harvest and stability of the predation rate. The 2012-2019 management plan of zone 17 had retained a growth rate

[7] Data from the mandatory registration of the non-Native hunters' harvest for the 2004 to 2008 hunting season and the voluntary reporting register of the Cree Trappers' Association for the period from July 2004 to June 2009. It is presumed that 50% of the calves reported by Natives are males.

considered modest, from 5% to 7%, which allowed an increase in the harvest rate up to 15%, while increasing the proportion of females hunted. According to this projection, the theoretical number of moose was supposed to increase to 2,800 over the duration of the plan, and the harvest potential rose from about 200 to 420 moose. These predictions were realistic, because the habitat quality did not seem limiting at these moose densities, and the predation rate was derived from recent population trend measurements (Morin et al., 2009). The main factor limiting the concretization of this projection depended on the ability of the organizations to maintain selective harvesting at a rate below 15%, particularly during the first years of implementation.

Based on non-Native hunting success, the 2009 survey measured the demographic peak of zone 17. The biggest non-Native harvest — 101 males — in this management context was recorded in 2010 with a 12% hunting success. The growth in the number of non-Native hunters continued up to 2012, but without increasing the number of moose killed, resulting in a reduction of hunting success. The number of hunters then decreased, without improving hunting success, which was maintained around 7% (Figure 3). Voluntary reporting of the Native harvest was also down, from 106 moose in winter 2013 to 37 moose in 2020 (Figure 2). It was impossible to measure a credible harvest rate according to the 2009 survey, due to irregularities in the voluntary reporting rate of the Native harvest. For example, the Native harvest decreased suddenly by an average of 37% from 2010 to 2012, compared 2009, and then rose back to plausible values (Figure 2). A few years later, the Cree tallymen addressed the Cree Trappers' Association to sound the alarm about possible moose overharvesting in zone 17, resulting from the hunting effort of all users. This testimony was supported by the reduction by half, since 2009, of non-Native hunting success and adult male harvesting. An update of moose demographics was therefore necessary to formulate appropriate wildlife management objectives.

The aerial survey of zone 17 covered by this report was conducted thanks to a financial and logistical collaboration of the Ministère des Forêts, de la Faune et des Parcs, the CNG, the Cree First Nation of Waswanipi and the CTA. A portion of zone 22, adjacent to zone 17, was inventoried simultaneously and these results will be the subject of a separate report. The results of the survey were sent to the HTFCC in September 2021 to allow assessment of the state of the population and issue a resolution that would favour achievement of management objectives in respect for the rights granted to the Crees under the JBNQA. This report was written after the deposit of an HTFCC resolution with the MFFP, in October 2021, establishing a maximum limit on kills at 104 moose for Natives and non-Natives. This resolution specifies that, under the JBNQA, all kills are reserved for Natives, because this limit is below the harvesting level of 158 moose guaranteed to the Crees.

This report presents the methodology, the logistics and the detailed results of the survey conducted in winter 2021 in hunting zone 17. The demographic parameters in the zone are interpreted in an assessment of the factors limiting the growth in the number of moose according to the state of knowledge of moose biology relating to habitat and leading predators.

STUDY AREA

Zone 17 is contained completely in the western spruce-moss bioclimatic subdomain. The average altitude varies from 200 to 400 m, gradually increasing toward the east of the zone. The landscape is composed of an amalgam of hills and flat expanses, punctuated by bodies of water and bogs. The forest stands are mostly composed of Black Spruce (*Picea mariana*), Balsam Fir (*Abies balsamea*), Jack Pine (*Pinus banksiana*) and Tamarack (*Larix laricina*). The deciduous tree species of the mixed stands, and composing the hardwood stands, are Paper Birch (*Betula papyrifera*) and Trembling Aspen (*Populus tremuloides*).

The total area of the zone, 23,373 km^2 was modified to 20,040 km^2 with the goal of extrapolating the moose density of the overflown parcels to an area that represents a potential moose habitat. This approach deletes the areas associated with the footprint of municipalities, anthropogenic infrastructures, and the main bodies of water, such as Lac Matagami, Lac au Goéland, Lac Waswanipi and Lac Chibougamau.

Forestry is practiced in a vast portion of zone 17. Since the 1960s, trees have been harvested on over 5,700 km^2 of the zone. According to the ecoforest mapping of the 4th decennial survey[8], at the time of the survey, the forest was characterized by 76.7% softwood stands (9,985 km^2), 19.1% mixed stands (2,491 km^2) and 4.3% (562 km^2) hardwood stands (Figure 4).

The forest road network includes about 16,000 km of roads, the condition of which varies in an unknown proportion between practicable gravel roads and sections not maintained and invaded by vegetation. Added to these roads are 9,300 km of winter forest roads, linear openings serving forest cutovers from gravel roads.

Under the JBNQA, zone 17 is mostly composed of Category III lands (20,176 km^2) where sport hunting is permitted. Hunting on the Category I and II lands is managed by the Band Councils of Waswanipi and Oujé-Bougoumou (Figure 5). In zone 17, the Category I and II land areas respectively total 597 and 2,279 km^2 for Waswanipi, and 139 and 168 km^2 for Oujé-Bougoumou. Zone 17 completely contains 22 Cree traplines (21 Waswanipi, 1 Oujé-Bougoumou) and its border crosses 23 additional traplines (15 Waswanipi, 7 Oujé-Bougoumou, 2 Waskaganish, 1 shared between Oujé-Bougoumou and Mistissini) (Figure 6).

[8] The ecoforest mapping of the 4th decennial inventory covers most of the zone, a portion of 475 km^2 dating from the 3rd inventory. The forest cover is interpreted from aerial photos dating from 2006 to 2013 for which the nature of the stands harvested burned subsequently was updated in 2020 (PEE_MAJ_2020). The composition of the forest cover was obtained from a query of field TYP_COUV = 'M' or 'F' or 'R'.

METHODOLOGY

The aerial survey was conducted according to stratified random sampling (Courtois, 1991). According to this method, the calculation of the number of moose in the zone is based on the count of a sample from the area of the zone. The parcels overflown to count moose were allocated randomly in the zone. The allocation of this sample considered that the moose habitat quality is not uniform on the scale of the zone. The parcels were allocated randomly according to a habitat quality mapping. The sampling effort was divided into two strata to ensure a representative of the habitats with high and low moose potential.

1.1 Sampling plan and analysis of the data

The sampling plan was mapped digitally with ArcGIS software version 10.4.1 (ERSI, 2011). The hunting zone was qualified in rectangular parcels of 60 km^2 (6 km × 10 km) according to a UTM spatial reference. Selection criteria for the parcels then were applied to ensure they constituted a moose habitat specific to the hunting zone. These criteria were not applied to the 100 km^2 Mercator units, as Courtois had proposed (1991) before creation of geomatics tools. Thus, the 60 km^2 marginal parcels with over 50% of their area situated outside the zone were excluded. The mapping of the hydrography on the 1:250,000 scale then was used to eliminate the parcels on which more than 20% of the surface consists of water. This threshold, slightly more critical than the one proposed by Courtois (1991), eliminated the parcels that were superposed on the large bodies of water in the zone. The parcels eligible for random selection of a subsample then were characterized according to the habitat quality with the goal of stratifying the sampling effort.

It is expected that the number of moose in a sector would be proportional to the value of the habitat quality index (HQI). The stratification was done on the basis of the habitat quality model initially designed for the Balsam Fir-Paper Birch bioclimatic domain (Dussault et al., 2006). This model was adapted to the spruce-moss forest (MFFP, unpublished data). The characteristics of the forest stands (species, age class, disturbance type, etc.) are described in detail by the ecoforest mapping. The model assigns a value to the forest stands according to the food and the cover serving as shelter for moose. The proximity between the food and shelter stands is also considered by the model, which assigns a value to the length of the border between them. For the calculation of the HQI, the study area is divided into a mosaic of 5 km^2 hexagons. A habitat quality score is produced for each hexagon according to the nature of the stands and the density of the territory. Each hexagon thus is characterized by a numeric value that allows mapping of the gradation of habitat quality by an index ranging from 0 (low) to 1 (high) (Figure 7). The habitat quality in an eligible survey parcel then is calculated according to the average HQI value of the hexagons it contains. The value of the hexagons crossed by the edge of a parcel is adapted according to the proportion of the area of the hexagon it contains (percentage of the area of the hexagon in parcel × value of the index). Zone 17 contains 4,915 hexagons for which the habitat quality value ranges from 0.04 to 0.86 ($\bar{X}$ = 0.45; standard deviation = 0.24).

The number of survey parcels overflown must be sufficient for the sample to produce a population estimate with an adequate margin of error (C.I. < 20%; $\alpha = 0.1$). The sampling must also be sufficient to detect and classify about 200 moose, which should guarantee statistical precision in the calculation of the sex ratio and recruitment. Because it is impossible to predict the variance of the sample, we used the results of the previous inventories to establish at 96 the number of parcels out of 306 eligible parcels, for a survey rate of about 30%. This sampling effort is analogous to that of the previous inventories of the zone and was supposed to allow allocation of a sufficient number of parcels in two strata, while maintaining budgetary realism.

The number of parcels to be overflown according to their habitat quality value previously was allocated arbitrarily to favour a greater number of parcels in sectors with a high index. This approach was inspired by the basic Neyman allocation principle, whereby the sampling effort must be modulated according to the variance of the expected result. Not knowing if the observations would corroborate our predictions, the possibility of stratification in the density analysis was evaluated and specified *post facto*. Stratification is possible only if the number of moose counted in a parcel is influenced by its HQI value, and the threshold between the two strata is defined according to this relationship.

Each of the parcels is overflown in 12 equivalent transects, on a north-south mapping axis, spaced 500 m apart. The helicopter pilot follows the route of the sampling plan on the screen of the navigation device and tries to maintain a ground reference altitude of 110 m (≈ 350 to 400 ft) and a speed of 160 km/h (Courtois, 1991). Two observers located in the back of the helicopter communicate their observations of trails, moose yards and moose to a navigator located in the front of the aircraft. These observations are compiled by the navigator on a GPS geolocation device and in a notebook, or on a Panasonic Toughbook tablet that displays a map and the digital observation capture form developed by the MFFP (Sebbane et al., 2013) for ArcPad 10.2 software (ESRI, 2011).

Once the transects of a parcel are overflown (Phase 1), mapping of the trails, the trail networks and the moose observed guides the navigator to produce the count and classification of a maximum number of moose (Phase 2). Despite the use of a helicopter and snow conditions conducive to detection of the trails, it is normal for a certain number of moose to go unnoticed. A 73% visibility rate was applied to increase the number of moose, as recommended by Crête et al. (1986). The moose density in the low and high strata was estimated by Invent.ori software (Leblanc et al., 1996), programmed in the R software (The R Foundation; Lavoie, 2019). The results are presented with their confidence interval (α = 0.1).

1.2 Logistics and crew coordination

Five crews composed of 19 people contributed as observers or navigators aboard the aircraft to the survey in zone 17 and a portion of zone 22. The Waswanipi crew proceeded with the survey from a family camp located in the forest. This crew finally overflew only parcels in zone 22, within reach of their base camp.

Compliance with the health protocols in the context of the COVID-19 pandemic constrained half of the crews. During this survey, the Cree communities were constrained by a lockdown indicated by the Direction de santé publique du Québec. The composition of the crews was therefore specific to the communities. Thus, the Waswanipi and Mistissini crews worked exclusively with the helicopter and the pilot assigned to them. The composition of the MFFP crews was established according to the availability of personnel, minimizing changes.

The technical training of the Mistissini and Waswanipi crews was delivered virtually, a few weeks before the survey. The sampling principles and the data capture format thus were presented to the crews in advance. The purpose of this training was to ensure the uniformity of the sampling and data capture conditions. The practical knowledge of these crews regarding the territory and tracking and identification of moose constituted facilitating competencies to appropriate the MFFP survey protocol.

The Mistissini crew travelled daily to Chibougamau when the conditions conducive to the survey were confirmed. Two MFFP crews were based in Matagami and one in Lebel-sur-Quévillon. The responsibility for the flyover of each survey parcel had previously been allocated among the crews. A review of crew coordination was conducted periodically based on their respective progress and the weather conditions conducive on the scale of the zone.

Refuelling was planned at the Chibougamau, Lebel-sur-Quévillon and Matagami airports. Moreover, the deposit of 118 barrels of jet fuel in 17 strategic caches was planned with the goal of optimizing flying time. Some of these caches were also provided to accomplish the survey of an adjacent sector in zone 22. The barrels were removed from these caches after the survey.

CONDITIONS OF PERFORMANCE

Generally, the weather conditions were conducive to the survey for 17 of 22 days, from February 11 to March 2, 2021. Weather constraints due to a light snowfall and overly dense cloud cover imposed a 4-day break from February 22 to 25, and a one-day break on March 1. During the survey period, the snow cover estimated by the weather station of the Meteorological Service of Canada at Matagami Airport varied from 62 to 71 cm, and from 51 to 57 cm at Chibougamau-Chapais Airport. No considerable snowfall was identified during the survey period. From February 21 to March 2, frequent wind gusts, varying from 31 to 78 km/h, helped facilitate the distinction of recent trails from old trails. The mean daily temperature of −16°C (standard deviation of 6°C) was the same for Matagami and Chibougamau.

Throughout the zone, the snow conditions were adequate to track moose, but the depth was insufficient to constrain their mobility. Combined with the low precipitation during the survey period, the moose search time was longer than foreseen, but without compromising its performance in compliance with the protocol and the budget.

A flyover of 96 parcels in zone 17 necessitated about 175 flying hours by 4 of the 5 crews mobilized for the simultaneous inventories of zones 17 and 22. The use of helicopters for the flyover of the two phases of the survey can be summarized at 1.8 flying hours/parcel, a value very similar to the flying time of the previous inventories, despite the use of aircraft during Phase 1.

The budget of this aerial survey of zone 17 was $312,680, or $54/km^2 surveyed. This amount excludes the salaries of MFFP, CNG, CTA and CFNW employees. The financial partnership represents an investment of $228,680 by the MFFP (73%) and $84,000 by the Canada Nature Fund administered by the CNG (27%). The CFNW financial contribution in kind was not quantified and was allocated mainly to the portion of the survey located in zone 22.

RESULTS

The number of moose in zone 17 was 1,036 ±15.8 % (α = 0.1). This confidence interval indicates that the number of moose in zone 17 is 873 to 1,200 individuals, based on 90% certainty. This calculation is based on the count of 232 moose in 139 moose yards contained in the 96 parcels overflown (Figure 8). The survey rate of the zone was 28.7%, allocated in two strata.

The average HQI value in a parcel showed a low positive relationship with the number of moose it contained. The 10 parcels that contain more than 5 moose were characterized by an average HQI value greater than 0.44 (Figure 9). This value was therefore used as a threshold to divide the low and high potential strata for moose. The low stratum comprised 39.2% of the moose habitat area in the zone and the high stratum comprised 60.8%. The survey rate of the moose habitat area in zone 17 was 14% in the low stratum (31 parcels) and 33% in the high stratum (65 parcels).

The moose density in the low stratum was 0.21 ±0.09 moose/10 km^2 and 0.71 ±0.15 moose/10 km^2 in the high stratum. Considering the proportion of low and high strata in the zone, the average density in zone 17 was 0.52 moose/10 km^2. According to the confidence interval of the estimate, the density would be 0.44 to 0.60 moose/10 km^2.

The size of the 139 groups of moose counted in the 65 parcels that contained moose varied from 1 to 15 moose. The absence of moose was recognized in 31 of the 96 parcels, i.e. in 17 low stratum parcels and 14 high stratum parcels (Figure 10).

Of the 232 moose counted, 13 could not be observed adequately for classification by sex and maturity. The results of the classification of 219 moose are presented with their confidence interval (α = 0.1). It is estimated that this zone was composed of 63.6 % ±3.9 adult females, 17.4% ±3.9 adult males and 19.0 % ±3.1 calves.

The sex ratio among the adults was 27.3 ±7.6 males/100 females. This represents a proportion of the sexes among the adults of 21.4% ±4.7 males and 78.6% ±4.7 females.

Recruitment was 29.8 ±5.8 calves per 100 females, the lowest value identified for this zone (Table 2).

The average annual population trend over the 11 years since the 2009 survey is −3.5%. The average moose density in zone 17 decreased from 0.78 moose/10 km^2 in 2009 to 0.52 moose/10 km^2 in 2021, down 33.3%. Because the moose habitat area was slightly smaller in 2021 than in 2009, the number of moose calculated for the zone would be 35% lower in 2021, compared to 2009 when the population was estimated at 1,582 moose.

All of the demographic data measured by this survey is presented in Table 1 for each of the two strata and for the entire zone. Some of this data can be compared to the results of the five previous inventories in Table 2 and Figures 11 to 13.

The average harvest rate during the positive and negative growth period of the moose population was calculated (Table 3). Arbitrary increases of 30% of the reported Native harvest and 10% of the non-Native harvest were applied to consider the voluntary nature of the Native harvest, losses by injury and poaching. According to these parameters, the non-Native harvest rate averaged 5.7% ±0.9 of the population from 2009 to 2021. The Native harvest rate would have averaged 8.5% ±1.9 (2020-2021 CTA register, unavailable at the time of writing). In short, the average harvest rate would have been about 14.4% ±1.8, a value analogous to the harvest rate of 15.1% ±1.7 identified during population growth, measured from 2003 to 2009. However, the total harvest rate since 2009 would be underestimated due to irregularities found in the voluntary reporting rate of the Native harvest. The non-Native harvest was limited to males over 1 year old. In fall 2021, the harvest of 41 moose represented 23% of the number of males estimated during the previous winter's survey.

Complementing the results of this survey, the gestation rate of females captured by the MFFP in 2018 and 2019 in the sector of zone 17 was measured by the hormone content of a feces sample. This analysis, based on 25 females over two years old, estimates the gestation rate at 88%, which corresponds to a normal value for this species.

DISCUSSION

Despite the use of different stratification methods during the inventories, the moose habitat potential in hunting zone 17 has been allocated similarly since 1985. The southwest of the zone is characterized by a higher density than the east and west portions. Before this survey, the stratification was typically produced according to the harvest density by hunting. The low number of moose harvested by non-Natives throughout the zone and the deficiencies of the Native harvest register limited the value of this information to stratify the sampling effort. The planning of this survey and the density analysis is preferably based on a habitat quality index. The moose density potential thus is calculated according to an interpretation of the value of the forest stands in terms of cover and food and their proximity. The development of an HQI specific to the western spruce-moss forest is in progress in the context of a moose behaviour study in the sector of application of the forest regime adapted from the Paix des braves (Humphries et al., 2021). This project compiles numerous moose behaviour data and local knowledge of Cree hunters that will be analyzed according to the ecoforest mapping. At term, this detailed perspective on moose behaviour will allow an in-depth interpretation of the results of this survey and will perfect the stratification of future inventories.

The low moose density is partially due to the absence of moose in several strata of the low and high strata. The stratification based on habitat quality compared to harvest density reduces the ability to distinguish in advance the high-potential sectors for moose that would have been overharvested by hunting, from the hospitable sectors where hunting is practiced sustainably. However, this limit of the method did not compromise the compliance of the margin of error. The actual density of the sectors where the moose population has been maintained therefore sometimes exceeds the average density of the high stratum. The previous inventories had shown that the subdivision into three or four strata did not improve the precision of the estimate. Indeed, the difference in density between certain strata was not significant and the high stratum was often limited to a very small proportion of the zone. Following the previous survey of zone 17, it had been recommended to allocate the sampling effort between two strata (Morin et al., 2009). The considerable gap between density and recruitment measured in the two strata supports the relevance of the method. The proportion of each stratum on the scale of the zone and their spatial distribution appear to be consistent with the non-Native harvest density (Figures 5 and 8). The high proportion of the zone located in the high stratum (61%) indicates that the habitat potential would be conducive to population growth.

In the boreal forest, the moose density was limited by the scarcity of quality habits throughout the landscape (Crête and Courtois, 1997). A study conducted in the sector of this survey had determined that the mature mixed stands would be the most productive of food and that they are strongly selected by moose, particularly in winter, as are the rare Balsam Fir stands (Jacqmain et al., 2008). Mapping of the moose yards by Cree hunters had shown the importance of these types of cover in this sector (Lajoie et al., 1993). In the Côte-Nord region, the convergence of moose and grey wolves in the mixed and hardwood stands, and in post-logging stands (Courbin et al., 2013; Gagné et al., 2016), also points to the importance of regenerating stands in the ecology of moose and their main predator. These stands are also conducive to hunting and are very important for the tallymen, especially since they are rare on certain traplines (Jacqmain et al., 2012). The maintenance of a sufficient area and the equitable spatial allocation of these stands among the traplines represent one of the planning challenges for forest operations. The Mixedwood Strategy was thus developed for the territory of the Paix des Braves adapted forestry regime (Dallaire et al., 2020). It identifies conservation thresholds for mature and regenerating mixedwood stands, based on reference proportions specific to a trapline. The objective of these thresholds is to maintain the biodiversity associated with these relatively scarce habitats in the region. The Cree-Quebec Forestry Board therefore values this strategy (CQFB, 2020), particularly to maintain a suitable habitat for moose. A considerable number of survey parcels of the high stratum did not contain any moose, which signifies that several mature mixed stands were overflown without detecting signs of moose. The proportion of these stands in the landscape would not be a cause of the population decrease in zone 17. Nonetheless, optimization of moose habitat potential remains an important issue in the managed spruce-moss forest.

Ecoforest mapping has provided a detailed profile of the forest cover of the zone for several decades. Since the 1970s, forestry changed the proportion of the hardwood and mixed stands and reduced the proportion of mature softwood cover in zone 17. The proportion of its area composed of mixed and hardwood stands had increased from 9% in the 1970s to 16% in 2000. An in-depth analysis of the survey parcels where the number of moose had increased in 2003 showed that the mixed and hardwood cover had increased from 12% to 30% since the 1980s (Leblanc, 2007). In the region, the allowable cut is mainly dependent on the productivity of the softwood cover, so the increase in the mixed and hardwood cover is a forest industry supply issue (Dallaire et coll., 2020). The progress of forest management since then has reduced the area by around 5% of softwood stands, 10% of mixed stands and 23% of hardwood stands inventoried since the early 2000s. In short, mixed and hardwood stands comprised 13% of the zone at the time of the survey, a value that remains higher than that of the forest of the 1970s (9%). However, the ecoforest mapping used for this profile is derived from the interpretation of aerial photos that could be over ten years old, for which the disturbances were updated annually until 2020. This profile thus is biased due to the non-inventoried growth of hardwood species over the past decade, but also as the result of the various silvicultural treatments intended to maintain softwood dominance of the regenerating cutovers. The update of the aerial photographs is scheduled for 2026 in the region and will provide a better profile of the zone.

Over the past 50 years, the disturbance regime and protection of forests against fires has led to recognition that the regeneration of logging areas is currently at the origin of a vast proportion of the habitats favourable to moose in zone 17. Thus, the logging operations[9] inventoried since the 1960s are at the origin of 44% of the mixed stands and 52% of the hardwood stands inventoried in 2020. The fires mapped over more than 100 years are at the origin of 7% of the mixed stands and 18% of the hardwood stands. Windfalls create openings in the softwood cover but are at the origin of only a very small proportion (less than 2%) of these stands. Management of this forestry legacy will be carried out according to the Mixedwood Strategy. This strategy allows for a reduction of more than 50% of mature mixedwood stands areas where their proportion in a trapline was at baseline greater than 1.5% (Dallaire et al., 2020). Ultimately, reaching this threshold would reduce the moose habitat potential in zone 17 compared to the current portrait.

In Québec, it is proposed that males should represent at least 30% of adult moose. This management threshold seeks to maintain the full productive potential of females in the application of selective hunting of males. In zone 17, hunting pressure has targeted males in a proportion of 78% (±5%) since 1996[10]. The observed proportion of 21% males among adults is the lowest inventoried for zone 17. Its potential effects on the population are difficult to interpret because the literature concerning the densities lower than 1 moose/10 km^2 and such a low proportion is rare concerning several aspects of moose biology. At moose

[9] Query PEE_MAJ_2020 = "ORIGINE" = 'CPHRS' OR "ORIGINE" = 'CPPTM_DIS' OR "ORIGINE" = 'CPPTM_U' OR "ORIGINE" = 'CPR' OR "ORIGINE" = 'CPRS_U' OR "ORIGINE" = 'CPT' OR "ORIGINE" = 'CRB' OR "ORIGINE" = 'CRR' OR "ORIGINE" = 'CRS' OR "ORIGINE" = 'CT' OR "ORIGINE" = 'ETR' OR "ORIGINE" = 'RECUP_C-T' OR "ORIGINE" = 'CBA' OR "ORIGINE" = 'CDV' OR "ORIGINE" = 'CEF' OR "ORIGINE" = 'CPH'.

[10] Data from the mandatory registration of the non-Native hunters' harvest for the 1996 to 2019 hunting season and the voluntary reporting register of the Cree Trappers' Association for the period from July 1996 to June 2020. It is presumed that 50% of the calves reported by Natives are males.

densities and proportions of males greater than those of zone 17, it is shown that female production and the duration of the calving period would not be influenced by selective hunting of males (Laurian et al., 2000). This comparative study also shows that the daily mobility rate of moose during rut did not differ in population density and lower proportion of males. The participation of young males in breeding would help mitigate the reduction of the encounter rate in a zone with a lower density of moose and males. In zone 17, the 88% gestation rate recently measured suggests that the number of males would not significantly limit female productivity. The participation of young males in breeding and fertilization in the second rut is possibly involved. The possible effective effects of the reduction in the proportion of males could be offset by the gain in productivity resulting from a higher proportion of mature females in the population. In practice, there were about 180 males in the entire zone at the time of the survey, a value lower than the one measured during the 1991 demographic slump (Table 2). The non-Native selective harvest rate for this segment had become too high. This hunting pressure on males was amplified by the Native harvest of moose over 1 year old, which would also be selective in an average proportion of 66% since 2009. The limit of 104 moose kills, established by the HFTCC, represents 58% of the number of adult males calculated in winter 2021. Harvesting females is therefore necessary in the continuation of kills by hunting. The decrease in the number of males thus considerably reduces the harvest potential in zone 17 due to the necessity of protection of females. In this demographic context, the HFTCC limit on kills is therefore not an objective to be achieved, but a threshold not to exceed to avoid the continuation of negative growth.

In the boreal forest, the study of the wolf-moose relationship is based on the theory that forestry increases the habitat potential for moose and consequently for wolves (Vanlandeghem et al., 2021). In principle, the growth of the number of prey results in predator density growth when prey density is the main limiting factor. This is limited by competition or territoriality (numerical response) and the prey consumption rate at which the predator reaches satiety (functional response). However, the predator-prey relationships are very complex due to the great diversity of natural ecosystems and anthropogenic interventions. After many studies, it was proposed that wolf predation would regulate the growth of a moose population when it reaches a density of 3 to 4 moose/10 km^2 (Messier, 1994). However, the main studies on this relationship are based on measurements in the moose populations with a density from at least 1 moose/10 km^2 to over 20 moose/10 km^2. A Yukon study measured predation rates higher than those known at low moose density (Hayes and Harestad, 2000). By extrapolating their model to very low moose densities, these authors suggest that predation could have a regulating effect to a density of 0.7 moose/10 km^2. In particular, this study points out that the spatial grouping of habitats of interest for moose could increase the predation rate in low moose density sectors. Because the high stratum averages 0.71 moose/10 km^2, it would be at the theoretical limit at which the predation rate could influence population growth. The considerable extent of the forest road network in zone 17 increases the probability of wolf predation of moose (Courbin et al., 2013) and could lower this limit. However, the density of 0.21 moose/10 km^2 in the low stratum is not favourable to the permanent establishment of wolf packs, because they would largely depend on random prey in this context (Messier and Crête, 1985). The predation rate by wolves thus would be reduced by the low density of moose in a vast portion of the northeast and in the western portion of the zone (Figure 6). In the high stratum, there is little likelihood that wolves will experience unprecedented growth when the forest landscape is similar to that of 2009 and the population of its main prey is decreasing.

Although it is shown that predation may be a major cause of death among moose, the predator-prey relationship dependent on moose density must be nuanced, particularly due to harvesting by hunting (Ballenberghe and Ballard, 1994). In zone 17, it is more likely that wolf density is indirectly regulated by the strong pressure of moose harvesting by hunting. The improvement of habitat quality by forestry and female protection measures had favoured considerable growth of the number of moose (Morin et al., 2009). Moose then had annual growth potential of over 20% when they were at 0.78 moose/10 km^2. This peak density is relatively very low and would not have supported a sufficient increase of the wolf population to reverse moose growth. Considering that moose productivity in zone 17 is not limited by competition for vegetation, there is little probability that the predation rate by wolves will exceed its growth potential. The growth of about 8% in the number of moose per year, observed from 2003 to 2009, has been transformed into average negative growth of 4% annually since 2009. According to the demographic predictions for zone 17 produced after the 2009 survey, a 14% harvest rate (Table 3) would have favoured maintenance of population growth (see zone 17 in Lefort and Massé [ed.], 2015). The inadequate monitoring of the Native harvest is a source of speculation on the causes of death. The irregularities of the reports to the CTA suggest that the 30% increase in the reported Native harvest, estimated in the 1980s and 1990s (Messier, 1993), would be inappropriate. The modelling exercise thus would underestimate death by hunting. It is therefore likely that the 29% decrease in the number of females and 40% in the number of males in the zone since 2009 is the result of overharvesting by hunting.

The low proportion of calves, particularly in the high stratum, indicates a recruitment problem in zone 17. Black bear predation black bears could be the main cause of death of calves (Franzmann et al., 1986; Patterson et al., 2013). The black bear density in the sector of zone 17 is little known but logging in the boreal forest would improve the habitat potential (Brodeur et al., 2008). Black bears are omnivorous, and their spring behaviour is influenced by the search where the vegetation is hospitable to their feeding. In the presence of a greater number of hospitable habitats, bears increase their mobility rate and incidentally cross habitats selected by moose for calving. The probability of encountering this opportunistic predator with calves thus would be increased in a habitat altered by forestry (Bastille-Rousseau et al., 2011). The population indicators monitoring the hunt indicate that the number of bears could be increasing. The average annual non-Native harvest in zone 17 more than doubled recently, from 44 bears in 2001 to 2010 to 95 bears in 2011 to 2020. The black bear hunting effort in the zone is partially inventoried by survey. According to this statistic, since 2010, it is estimated that hunting success in zone 17 would be maintained at a value slightly higher than the provincial average, despite a considerable growth in hunting pressure. It is therefore perceived that the black bear population in zone 17 is in good health and that its density is probably higher than that of other hunting zones also located in the spruce-moss forest (G. Szor, personal communication). Considering that the moose gestation rate would be normal, and that Native hunting essentially happens in spring, the low recruitment measured in winter 2021 (30 calves/100 females) would mainly be due to predation. The number of calves killed by bears compared to those killed by wolves and hunting remains little known in zone 17, however. The 19% proportion of calves in the population — estimated before the spring mortality— shows a reduction of growth potential since the previous survey in 2009. This result is cause for greater concern, because the number of females in zone 17 in 2021 was greater than the number measured in 2003 (Table 2), when the population was comparable in abundance and beginning strong growth.

CONCLUSION

The state of knowledge of moose population management principles is excellent. Hunting zone 17 has been the object of many inventories and expert opinions. Wildlife management in the zone has been supervised by the HFTCC for over 40 years. It has been demonstrated periodically that the number of moose in zone 17 would mainly be regulated by hunting. The results presented in this report support this finding. Selective hunting of males favours recruitment potential by increasing the proportion of females among the adults. The small number of males in the zone reduces the harvest potential by hunting when protection of females is a priority. The population decrease documented by this survey seems in part to be due to an increased calf mortality rate, probably by predation. The adapted forest regime can create and maintain a quality habitat for moose, but also for black bear. The number of females has decreased greatly since 2009, showing a very high mortality rate despite the low probability of an increase in the predation rate by wolves. The interpretation of negative growth of moose is limited by inadequate monitoring of the Native harvest, which underestimates its effect. The ecosystem of zone 17 would still be favourable to the growth in the number of moose in a context of sustainable management of hunting.

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Table 1. Results of the aerial survey of zone 17 conducted in winter 2021, presented for the low and high strata and for the average of the zone (C.I. α = 0.1).

Strata	**Survey rate**	**Stata weight**	**Density** (moose/10 km²)	**Ratios per 100 females**		**Proportion of adults (%)**		**Proportion in the population (%)**		
				Males	Calves	Males	Females	Males	Females	Calves
Low	23.7%	39.2%	0.21 (0.09)	31.2 (3.3)	43.8 (2.0)	23.8 (2.0)	76.2 (2.0)	17.9 (1.8)	57.1 (1.4)	25.0 (1.2)
High	32.0%	60.8%	0.71 (0.15)	26.6 (6.9)	27.4 (5.5)	21.0 (4.2)	79.0 (4.2)	17.3 (3.6)	64.9 (3.6)	17.8 (2.9)
Zone	**28.7**%	n/a	**0.52** (0.08)	**27.3** (7.6)	**29.8** (5.8)	**21.4** (4.7)	**78.6** (4.7)	**17.4** (4.1)	**63.6** (3.9)	**19.0** (3.1)

Table 2. Comparison of the demographic structure of moose measured by 6 aerial surveys in zone 17 since 1985 (C.I. α = 0.1).

Survey year	**Number of plots**	**Estimated number of moose**	**C.I. estimate** (α = 0.1)	**Density** (moose/10 km²)	**% Males among adults**	**Ratios per 100 females**		**Adult population**	
						Males	Calves	Number of males	Number of females
1985	53	1140	33.0 %	0.50 (0.17)	35.4 (11.0)	77.6 (24)	41.4 (7.3)	344 (113)	443 (146)
1991	101	667	25.5 %	0.29 (0.07)	35.6 (7.5)	55.4 (6.3)	35.4 (5.7)	186 (47)	336 (86)
1996	125	836	16.7 %	0.42 (0.07)	34.5 (4.9)	52.7 (11.1)	70.3 (10.0)	197 (33)	374 (63)
2003	110	983	18.2 %	0.45 (0.08)	30.6 (5.9)	44.1 (12.3)	42.1 (9.3)	233 (42)	528 (96)
2009	127	1581	13.5 %	0.78 (0.11)	25.4 (3.7)	34 (6.7)	45.9 (7.1)	299 (40)	879 (119)
2021	96	1036	15.8 %	0.52 (0.08)	21.4 (4.7)	27.3 (7.6)	29.8 (5.8)	180 (28)	660 (104)

Table 3. Estimate of the harvest rate of the population in the winter preceding the harvest, according to the annual average population estimate between the 2003 and 2009 inventories (λ = 1.082), and then from 2009 to 2021 (λ = 0.965).

Year of population estimate (t)	Non-Native harvest year	Native harvest year	Population estimate	Harvest rate (%)[11]			Reported non-Native harvest	Reported Native harvest			
				Non-Natives	Natives	Minimum		Maximum	Males	Females	Calves
2003	2003	2002-2003	**983**	4.7	7.5	12.2	42	42	21	16	5
2004	2004	2003-2004	1064	5.3	9.8	15.1	51	72	35	23	15
2005	2005	2004-2005	1151	7.3	9.2	16.6	76	74	44	21	10
2006	2006	2005-2006	1246	7.1	7.8	15.0	80	75	38	29	7
2007	2007	2006-2007	1349	7.3	7.6	14.9	89	53	26	17	10
2008	2008	2007-2008	1460	6.2	10.8	17.1	82	114	62	38	14
Average				**6.4**	**8.8**	**15.1**	**70**	**72**	**38**	**24**	**10**
Standard deviation				**1.1**	**1.4**	**1.7**	**19**	**24**	**14**	**8**	**4**
2009	2009	2008-2009	**1581**	5.2	9.4	14.6	74	103	60	29	14
2010	2010	2009-2010	1527	7.3	8.7	16.0	101	106	73	26	7
2011	2011	2010-2011	1474	7.2	6.3	13.5	96	63	34	16	13
2012	2012	2011-2012	1423	5.7	8.1	13.8	73	69	38	22	10
2013	2013	2012-2013	1374	4.7	10.9	15.6	58	106	51	34	21
2014	2014	2013-2014	1327	6.3	10.8	17.1	75	103	57	30	15
2015	2015	2014-2015	1281	5.6	10.5	16.0	64	94	59	21	15
2016	2016	2015-2016	1236	5.3	9.7	15.0	59	93	49	29	15
2017	2017	2016-2017	1194	5.9	7.3	13.1	63	63	36	21	6
2018	2018	2017-2018	1152	5.3	6.5	11.8	55	56	25	16	14
2019	2019	2018-2019	1112	6.1	5.5	11.6	61	45	21	17	8
2020	2020	2019-2020	1074	5.2	N/A	N/A	50	37	21	13	4
2021	2021	2020-2021	**1036**	4.5	N/A	N/A	42	n/d	n/d	n/d	n/d
Average				**5.7**	**8.5**	**14.4**	**67**	**78**	**44**	**23**	**12**
Standard deviation				**0.9**	**1.9**	**1.8**	**17**	**25**	**17**	**7**	**5**

[11] The calculation of the harvest rate considers the following parameters: the proportion of the Native harvest for a season is adjusted arbitrarily to be 70% in spring of the year of the estimate (t) and 30% in fall (t+1); the reported harvest is augmented arbitrarily according to a Native reporting rate of 70% and a non-Native reporting rate of 90%, so as to consider the voluntary nature of Native harvest reporting, poaching and losses by injury; e.g. the harvest rate is the proportion of the February 2010 population harvested in spring 2010 (70% of the 2009-2010 Aboriginal harvest augmented) + fall 2010 non-Aboriginal harvest + fall Aboriginal harvest (30% of the 2010-2011 Aboriginal harvest augmented).

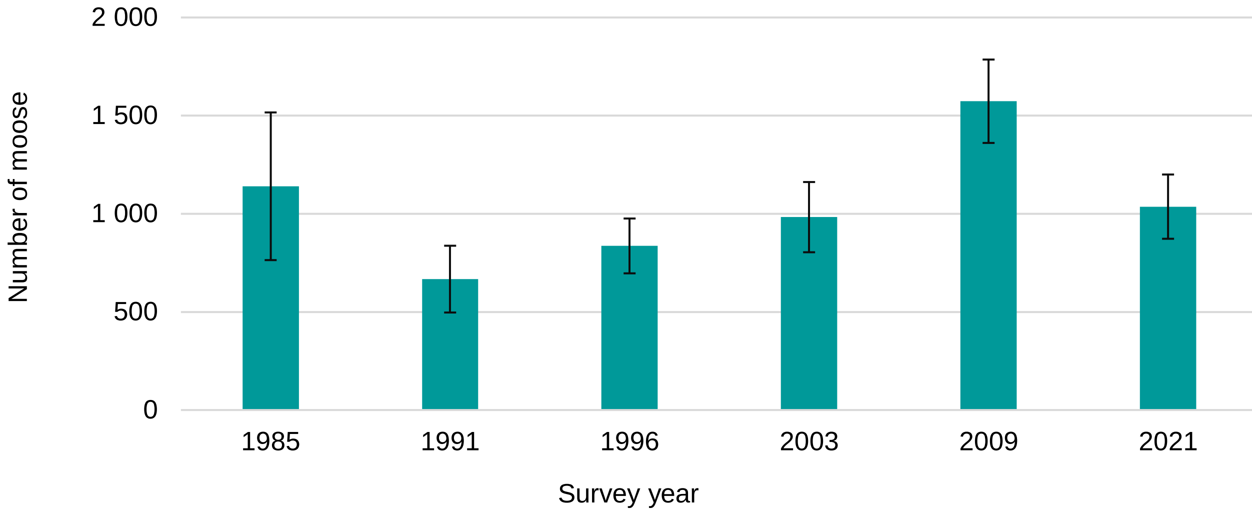

Figure 1: Number of moose (C.I. 90%) estimated by the six aerial inventories conducted in hunting zone 17 from 1985 to 2021.

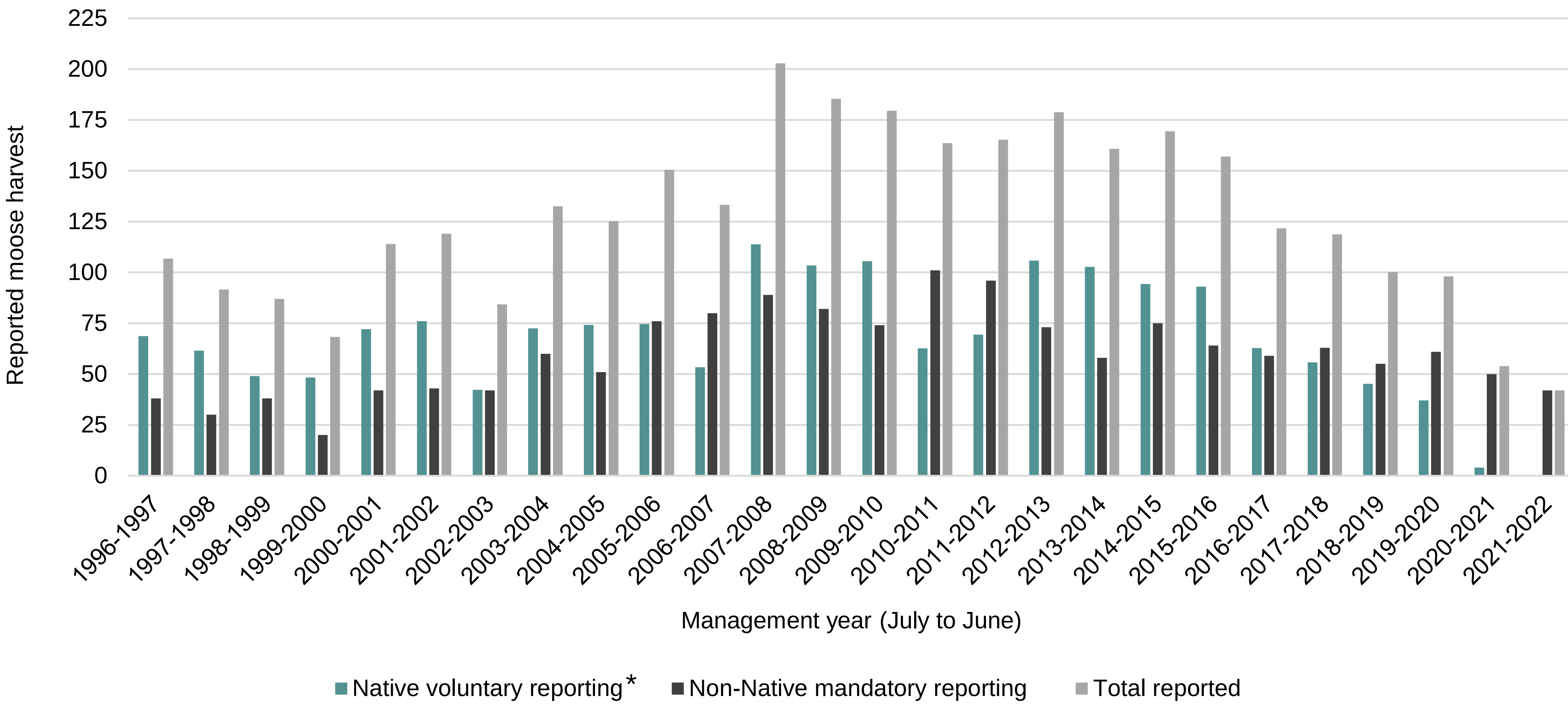

Figure 2: Estimate of the annual moose harvest in zone 17 based on the voluntary reporting register of the Cree Trappers' Association and mandatory reporting of kills for non-Natives

***** The harvest reported on a voluntary basis on a trapline is multiplied by the proportion of the areas of the trapline superposed in zone 17.

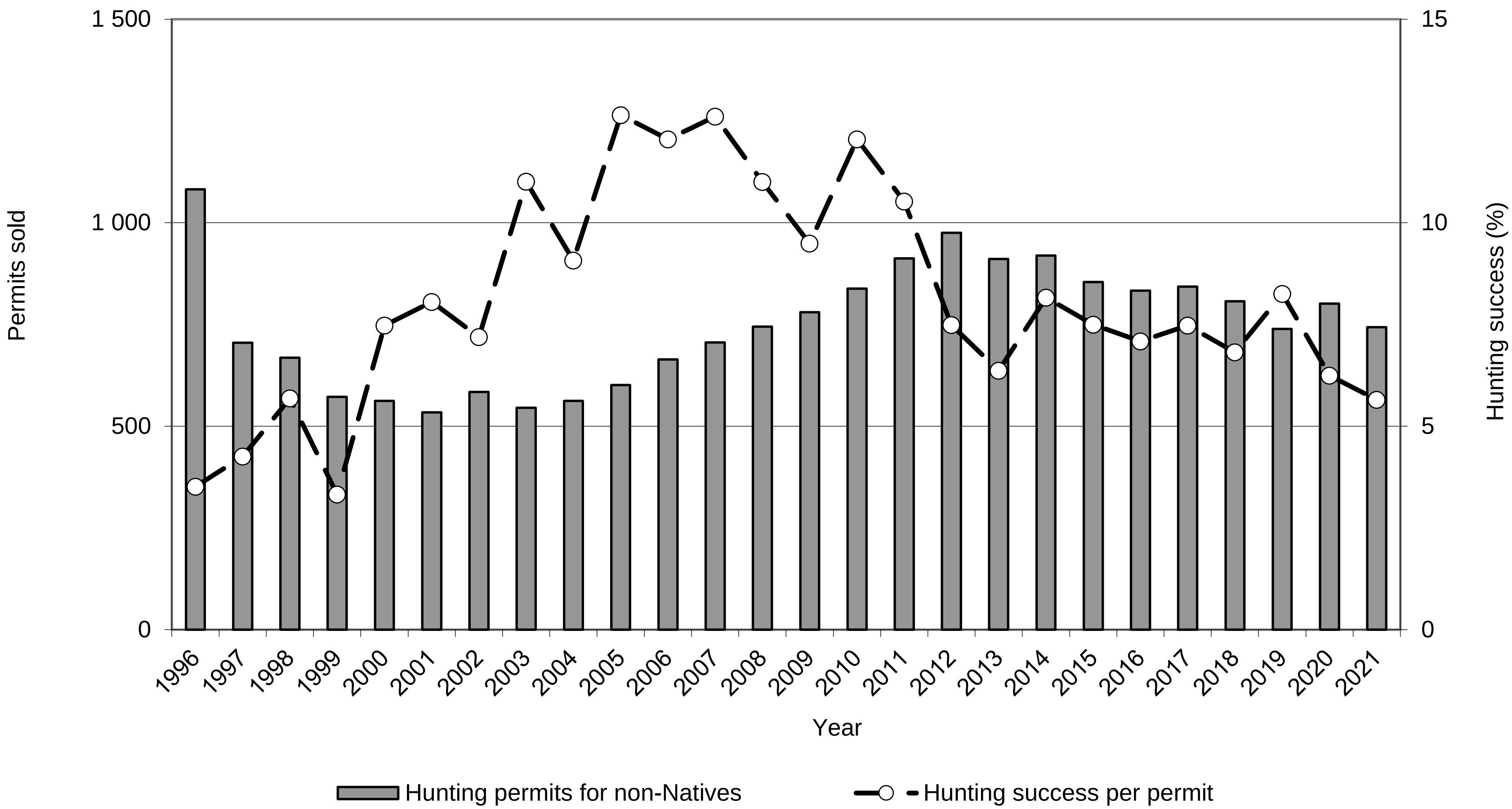

Figure 3: Number of hunting permits purchased by non-Natives to hunt specially in zone 17 from 1996 to 2021 (left axis) and hunting success per permit* (right axis).

* Hunting success corresponds to the percentage of hunters who had procured a permit for zone 17 and who killed a moose. In zone 17, two permits are required to kill a moose. The maximum hunting success therefore is theoretically 50% of hunters, or 100% of groups of two hunters.

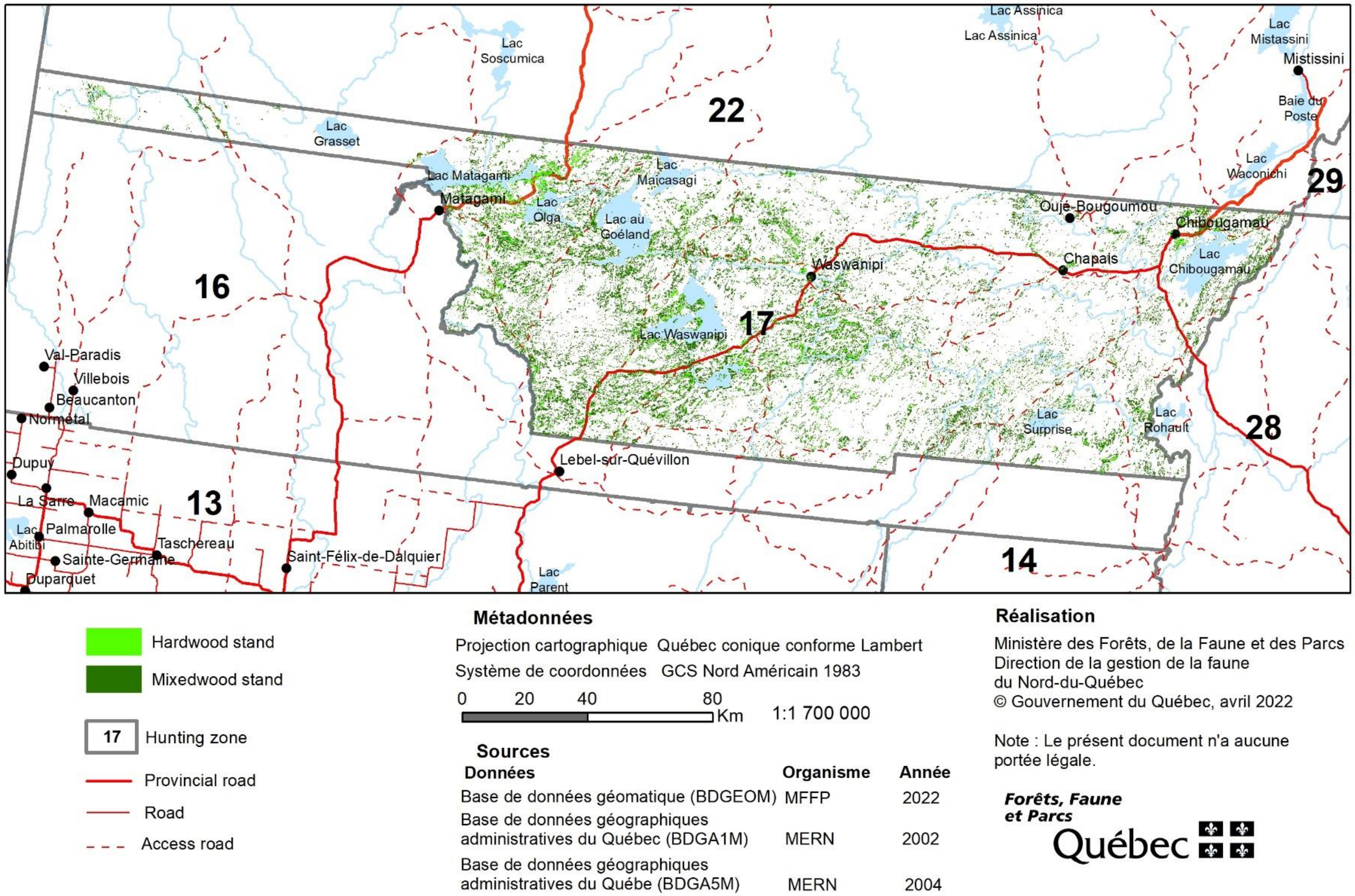

Figure 4: Spatial allocation of mixed stands (composed of softwood and hardwood trees) and hardwood stands in zone 17 according to the ecoforest mapping of the 4th decennial survey for which the disturbances are updated in 2020.

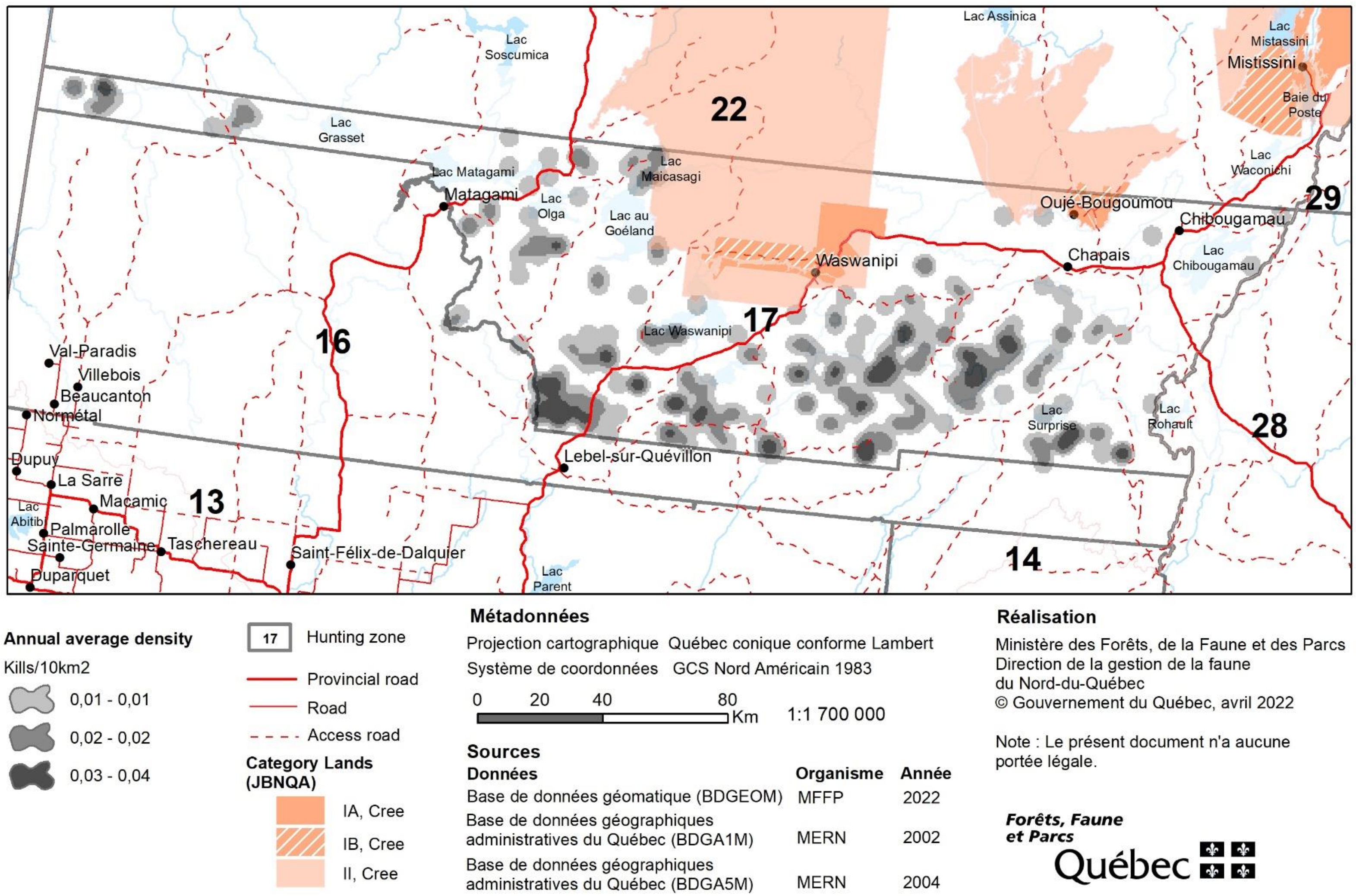

Figure 5: Mapping of the average annual density of the sport harvest over five years, from 2017 to 2021 in zone 17.

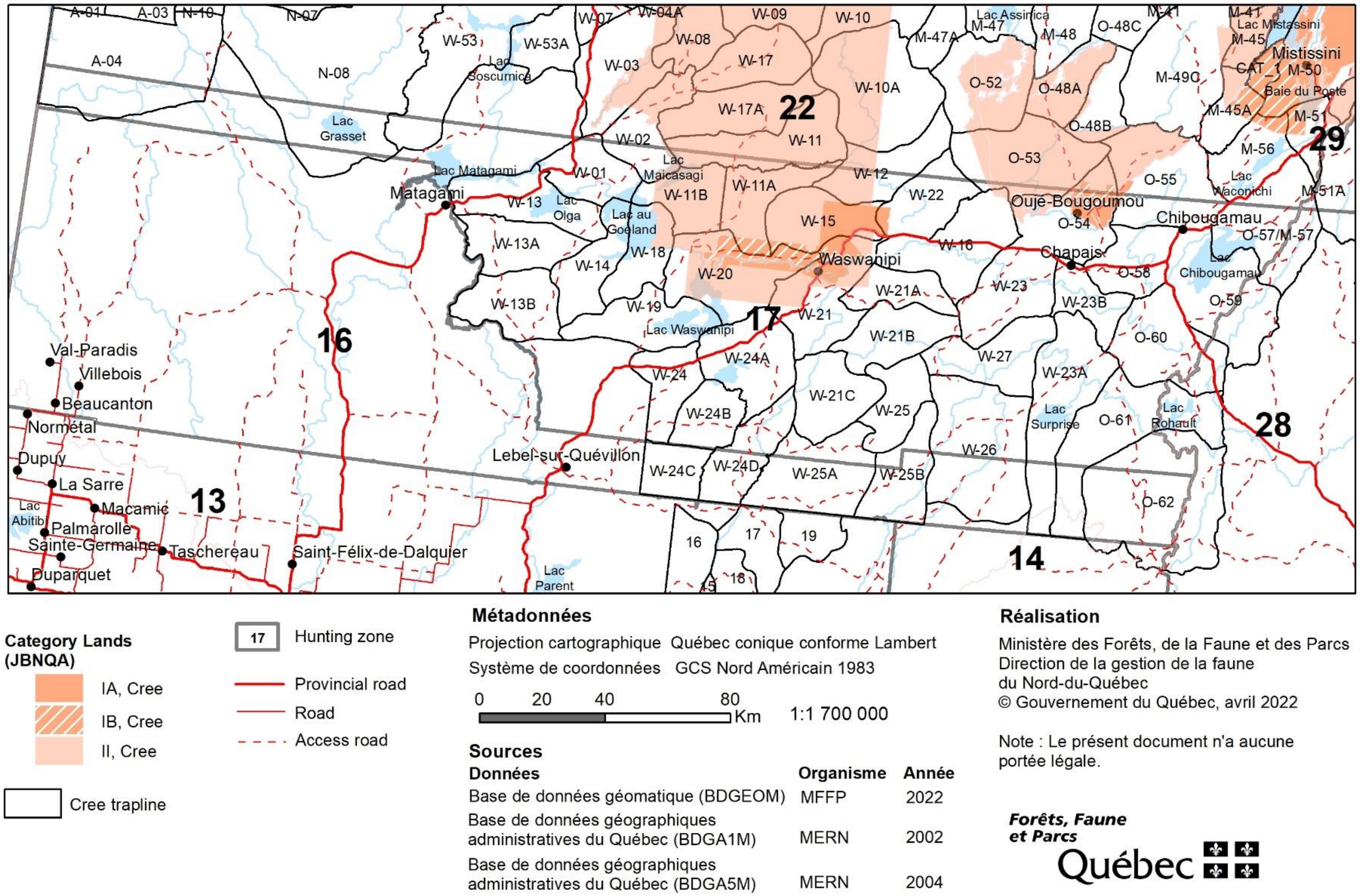

Figure 6: Location of zone 17 relative to the Category I and II lands and the Cree traplines defined in the James Bay and Northern Québec Agreement.

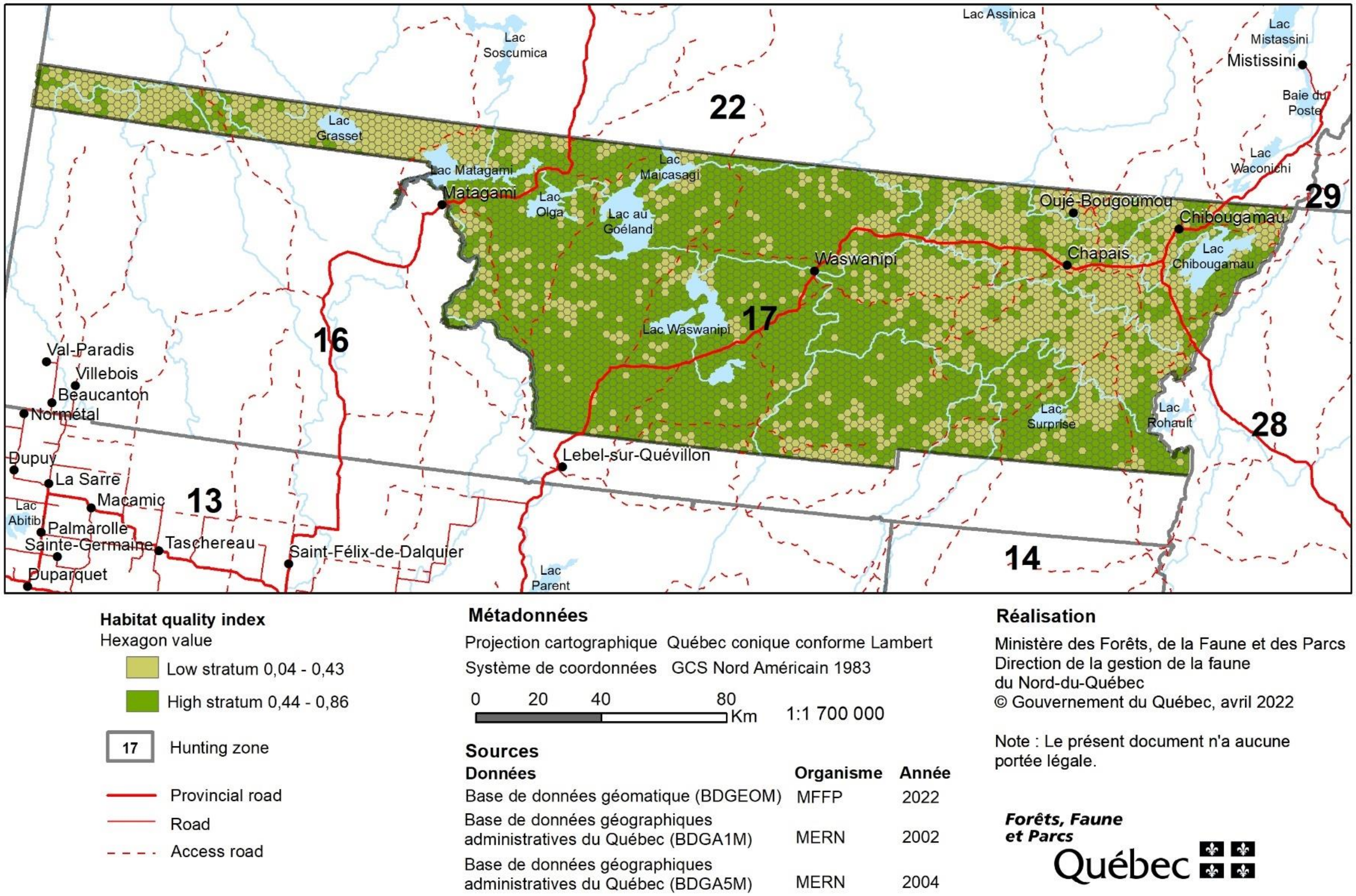

Figure 7: Moose habitat quality index in the 5 km² hexagons covering hunting zone 17, represented according to the low and high strata based on the threshold established at 0.44.

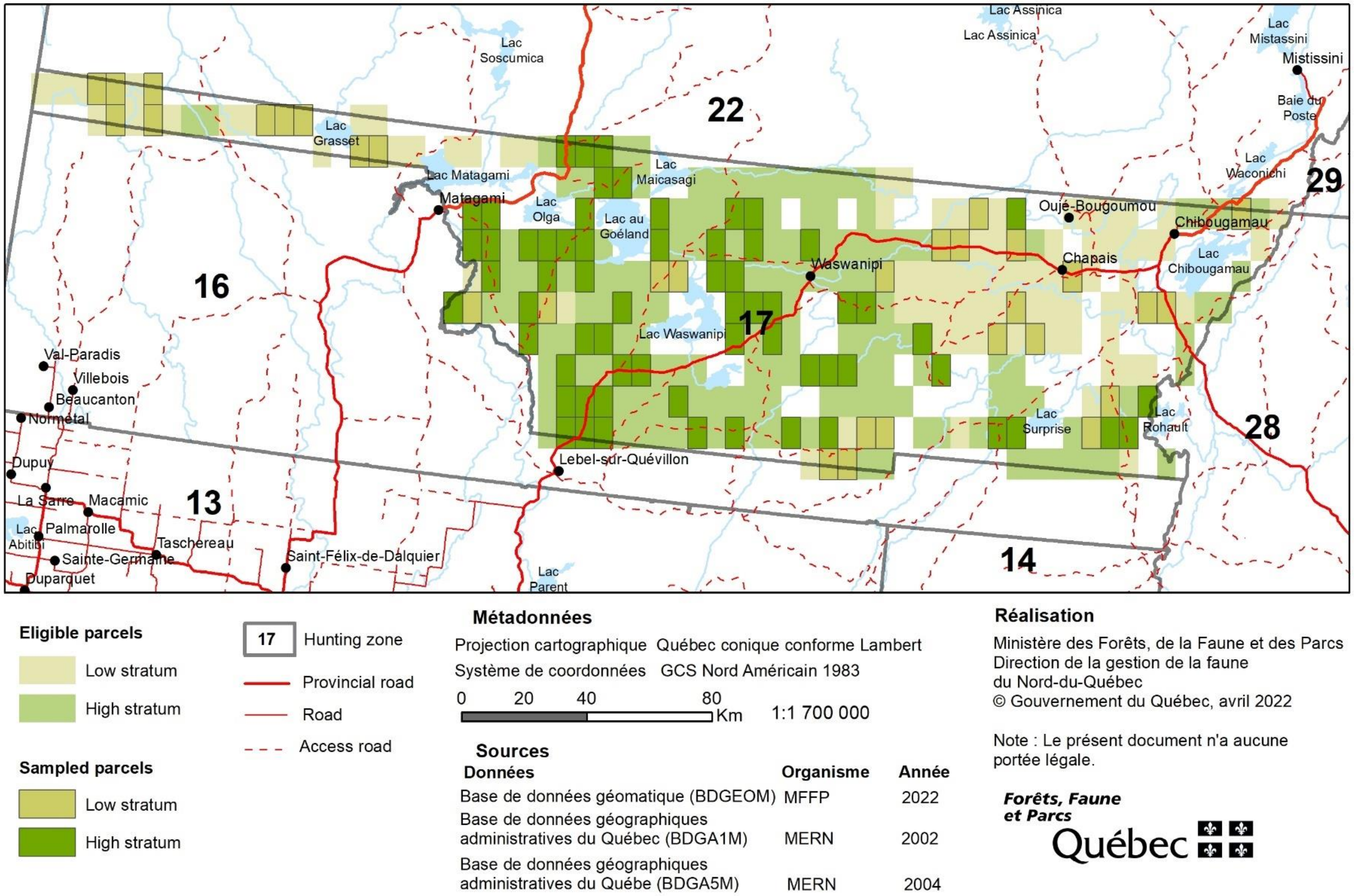

Figure 8: Random allocation of the parcels sampled during the aerial moose survey in winter 2021 in zone 17 relative to the eligible parcels in the low and high strata and the operating bases of Matagami, Lebel-sur-Quévillon and Chibougamau.

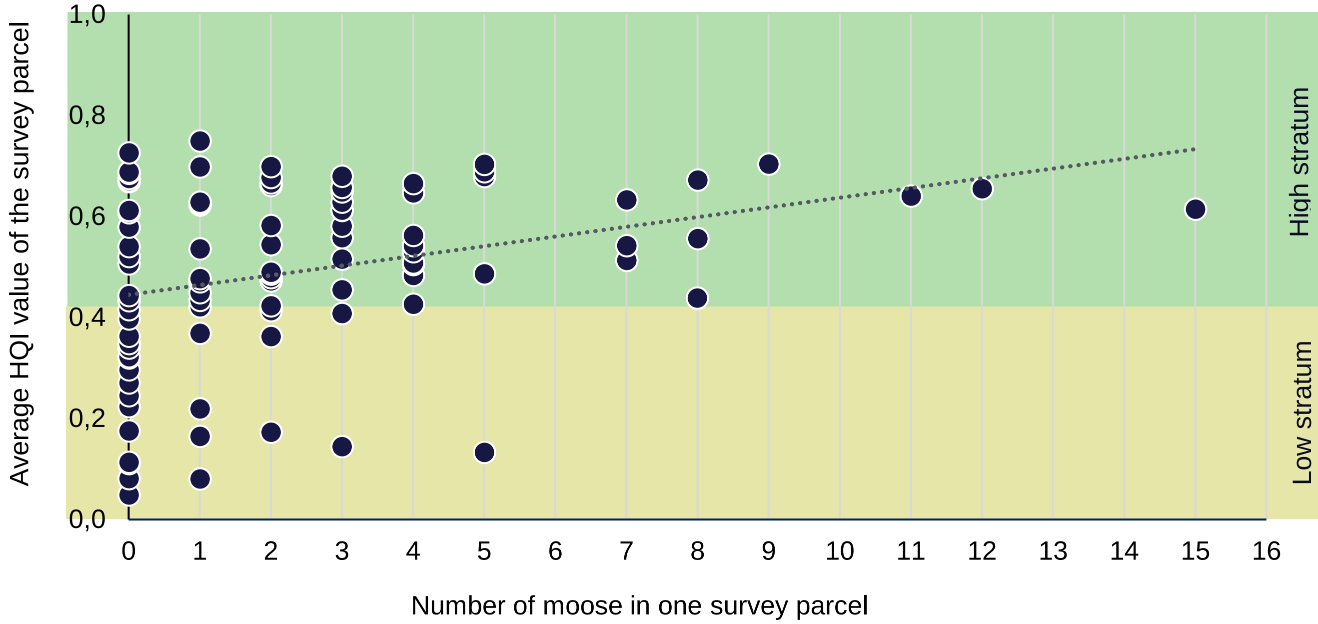

Figure 9: Number of moose counted in each 60 km^2 survey parcel according to its average HQI value (dotted-line trend curve : y = 0.019x + 0.45; R^2 = 0.099).

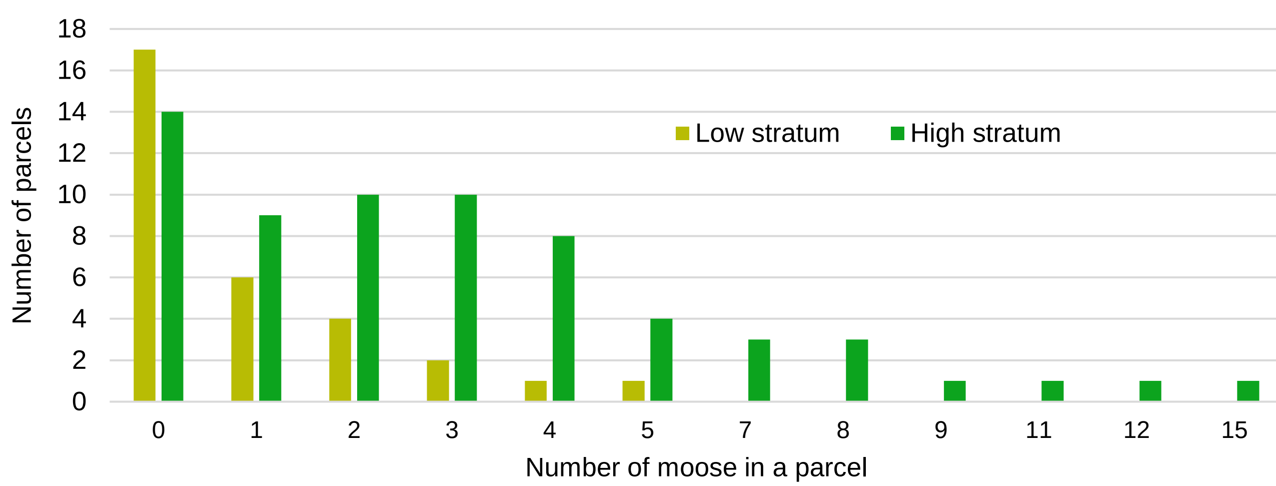

Figure 10: Frequency of the result of the moose count in the 96 parcels overflown during the moose survey of zone 17 in winter 2021.

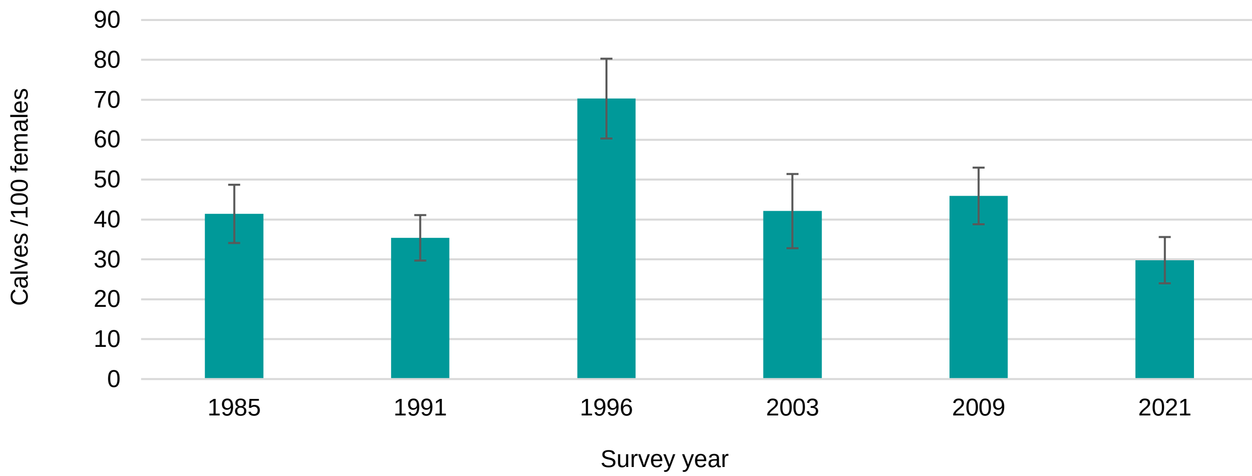

Figure 11: Ratio of the number of calves per 100 females (± C.I. 90 %) calculated according to the count of the aerial inventories conducted in zone 17 since 1985.

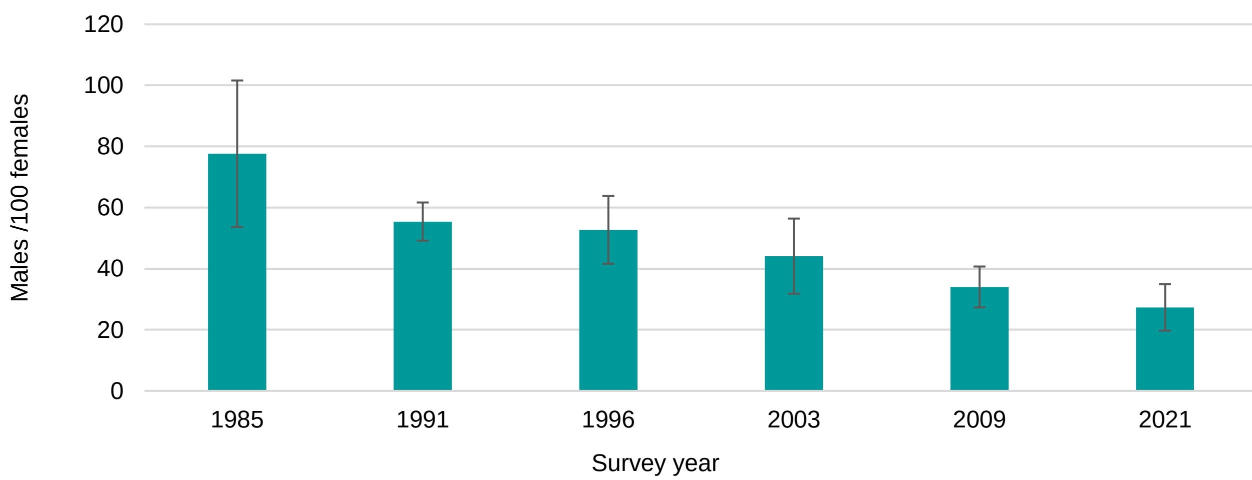

Figure 12: Ratio of the number of males per 100 females (± C.I. 90 %) calculated according to the count of the aerial inventories conducted in zone 17 since 1985.

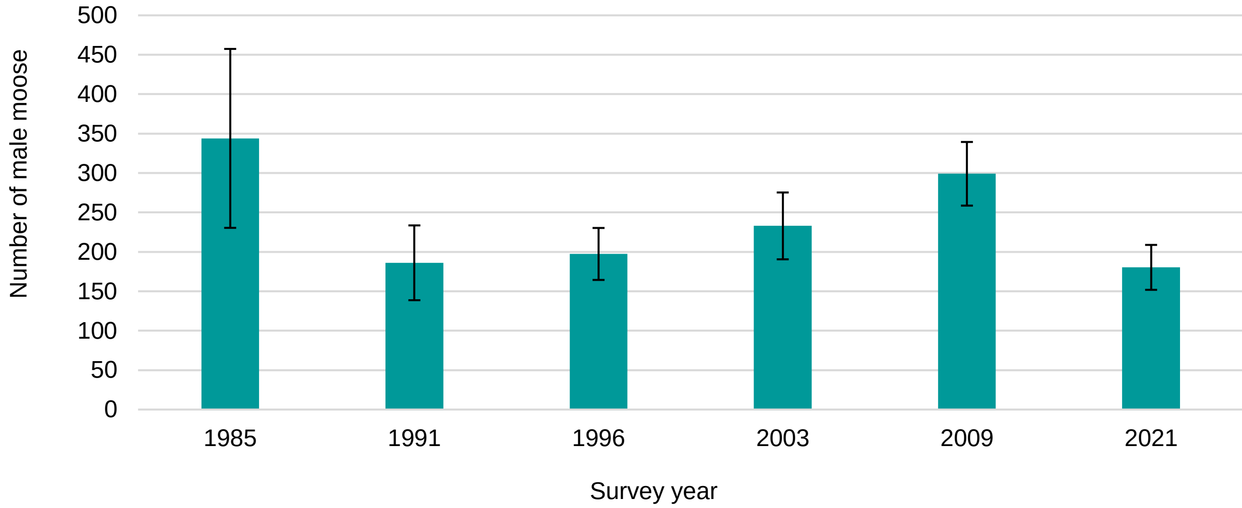

Figure 13: Number of males (> 1 year old) in zone 17 (± C.I. 90%) estimated according to the moose classification during the aerial inventories conducted since 1985.

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