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Influence of meteorological conditions on daily Kilometric Abundance Index in moose's populations assessement in east-central Finland and characterization of thei winter habitat

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INFLUENCE OF METEOROLOGICAL CONDITIONS ON DAILY KILOMETRIC ABUNDANCE INDEX IN MOOSE'S POPULATIONS ASSESSEMENT IN EAST-CENTRAL FINLAND AND CHARACTERIZATION OF THEIR WINTER HABITAT

POSSET JONATHAN

TRAVAIL DE FIN D'ÉTUDES PRÉSENTÉ EN VUE DE L'OBTENTION DU DIPLÔME DE MASTER BIOINGÉNIEUR EN GESTION DES FORÊTS ET DES ESPACES NATURELS

ANNÉE ACADÉMIQUE 2018-2019

CO-PROMOTEURS : LICOPPE ALAIN, *ULIÈGE*
BECKER LAETITIA, *DEEP KARELIA*

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MASTER THESIS IN ORDER TO GET A MASTER DEGREE IN BIO-INGINEERING WITH A SPECIALIZATION IN FOREST AND NATURAL AREAS MANAGEMENT

ACADEMIC YEAR 2018-2019

CO-SUPERVISORS: **LICOPPE ALAIN, *ULIEGE***
BECKER LAETITIA, *DEEP KARELIA*

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Abstract

English

Wildlife population assessment has taken more and more importance through recent years. In Finland, the main used method for population estimation is called “Track counting” and leads to a Kilometric Abundance Index (KAI). As moose takes an essential place in Finnish forestry, it is surveyed each winter thanks to this method. Besides, there is a need in understanding winter habitat selection in order to adjust its management. This study is divided into two main parts: the first one aims to study the impacts of meteorological conditions on daily KAI, the second part focuses on localisation and characterization of winter habitat. For KAI study, three 10km-odd transects have been randomly dimensioned and walked every week from 22nd of January to 23nd of April 2019. New moose’s tracks from last week were counted and a daily KAI was estimated (tracks seen per 10km per day). Best subset method was used to select the model that better predicts KAI according to meteorological parameters. For winter habitat determination, fresh moose’s tracks were followed to localise droppings and resting places. Zones with a high density of found items were considered as preferred habitat. For those habitats, vegetation surveys were conducted, thanks to 5x5m quadrats, both inside and outside the preferred habitats. One-way Anova were achieved in order to highlight differences in terms of vegetation parameters. The built model includes snow depth, snow sinking and daily maximal temperature ($r^2=0.54$). KAI increases with an increasing snow sinking and decreases with the increases of the two other parameters. Results of winter habitat determination have pointed out a difference in trees layer, with more trees in adjacent vegetation (p-value=0.033). In shrub layer, number of individuals is generally higher in preferred habitats (p-value=0.045), with birch (*Betula sp.*) and pine (*Pinus sylvestris*) as main found species. Results of this study, both in KAI and winter habitat selection, could help forest manager decision-making process while surveying moose.

Français

Depuis les récentes décennies, l'évaluation des populations d'animaux sauvages a pris de plus en plus d'importance. En Finlande, la méthode utilisée pour l'estimation de population animale consiste en un relevé d'un Indice Kilométrique d'Abondance (IKA), en comptant chaque hiver, le nombre de traces dans a neige le long d'un transect. L'élan fait partie des espèces suivies par cette méthode, vu son importance dans les écosystèmes forestiers finlandais. En plus de ces estimations, une meilleure compréhension de la sélection d'habitat hivernaux est primordiale. Les objectifs de cette étude sont divisés en deux sections : la première vise à évaluer l'influence des conditions météorologiques sur l'IKA et la seconde partie s'intéresse à la localisation et caractérisation des habitats hivernaux préférentiels. Pour estimer un IKA journalier, trois transect d'environ 10km ont été aléatoirement reparti sur la zone d'étude et parcouru chaque semaine du 22 janvier au 23 avril 2019. Toutes nouvelles traces d'élans repérés ont été comptées et un IKA journalier a été estimé (nombre de traces vues par 10km par jour). La méthode des best-subset a été utilisé pour déterminer le meilleur modèle permettant de prédire l'IKA selon les différents paramètres météorologiques. Pour l'étude des habitats hivernaux, plusieurs traces fraiches ont été suivis afin de géolocaliser les crottes et couches. Les zones avec une plus grande densité ont été considérés comme habitats préférentiels. Pour ceux-ci, une comparaison de végétation avec la végétation adjacentes a été réalisé par la mise en place de quadrats de relevés. Des Anova à un facteur ont permis d'identifier les différences entre les principales variables mesurées. Le modèle construit permet une estimation correcte de l'IKA ($r^2 = 0.54$) sur base de la profondeur de neige, de l'enfoncement et de la température maximale journalière. Ainsi, l'IKA augmente avec l'augmentation de l'enfoncement et diminue avec l'augmentation des deux dernières variables. Les résultats de l'étude des habitats hivernaux ont montré une différence significative du nombre d'arbres comptés, en moyenne plus élevés dans la végétation adjacente (p-valeur=0.033). Dans la strate herbacée, il y a en moyenne plus d'arbustes dans les habitats préférentiels (p-valeur=0.045), avec une grande présence de bouleau (*Betula sp.*) et de pin (*Pinus sylvestris*). Les resultats de cette étude, que ce soit sur l'IKA ou sur la sélection d'habitats, fournissent des informations concrètes utiles à tout gestionnaire forestier pour la gestion de populations d'élans.

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1 Introduction

Wildlife management takes more and more place in our society, especially for activities linked with environment. Animals are an integral part of natural ecosystems, providing ecosystem services. Disturbance in such ecosystem can impact the equilibrium between species and their environment, leading to problems such as natural disaster or loss of biodiversity. Therefore, there is a need in protecting biodiversity from all disturbances, by setting up actions in order to preserve their well-being. This way, first step in animal's management is population assessment, giving information about population to protect. Several estimation methods exist, each of them having their own characteristics (Sebber, 1986; Pollock, 2002). Using one of them instead of another depends on several criteria, such as the goal of the estimation, the accuracy needed, or the financial mean (Rönnegård, 2008).

In Finnish forestry, the main used method to assess wildlife population is the snow track counting method (Pellikka, 2005). Briefly, this method consists of counting animal's footprints over several 12km transects, randomly distributed through the territory. It leads to a Kilometric Abundance Index (KAI), number of footprints seen per 10km per day, and classified according to geographical areas. Therefore, zones with a higher index will be considered as high-density areas. As Finland has a permanent snow cover of six months every year, this method is widely accepted as efficient and suitable.

One of the surveyed species by the Finnish Game and Fisheries Research Institute is moose (*Alces alces*), determinant species in Finland. It takes an important place in forestry ecosystem. Firstly, it constitutes about 85% of Finnish wolve's diet (Gade-jorgensen, 2000). Secondly, there is a hunting pressure on moose, and since three years, more than 45,000 animals have been killed during the hunting season (Riistahavainnot, 2019). Moreover, with a growing population, moose lead to several damages on trees, impacting the main economic resource of the country (Ball, 2002). Therefore, there is a crucial need in assessing its population and understanding its behaviour. However, as moose adapt their movement according to snow conditions (Lundmark, 2008), KAI can change from day to day, over the winter. This way, it could be interesting to observe how snow conditions affect snow track counting method results.

Second step in animal's management is the comprehension of behaviour, leading to habitat and diet determination. In Finland, moose's habitat is generally composed of young regeneration trees (Timmermann, 1988). It provides food with high nutrients values, especially in winter, when rough conditions reduce the amount of vegetation available. In order to improve forest management to moose's behaviour, mapping moose's winter habitat could lead to accurate localisation of preferred zones. Moreover, a good knowledge of these preferred zones is crucial for sustainable long-term management.

This study focuses therefore on two aspects: Kilometric Abundance Index and winter habitat selection. It first aims to study the impacts of meteorological parameters on KAI. This way, a model enabling a to two aspects: Localisation and characterization.

2 Ecology and management of moose

Ecology of Moose

Moose, *Alces alces*, is the biggest representant of the Cervidae family, with an average shoulder height of 200cm (Clutton-Brock, 1980). Males and females can respectively reach a weight of 500 kg and 300 kg (Solberg, 1994; Sand, 1996), and life span does generally not exceed 20 years. Worldwide represented, both in Eurasia and northern America, it occurs generally in tundra and boreal forests, but some groups can be found in temperate forests (Fig. 1). In Europe, its range goes from northern Sweden to Poland, with a decreasing population from north to south (IUCN, 2015). This species is marked as a least concerned in the IUCN red list, with a world number of 1.5 billion. Even more, there is an increasing population in Europe for 50 years, with an average number of 500,000 animals in the continent, Russia included (IUCN, 2015).

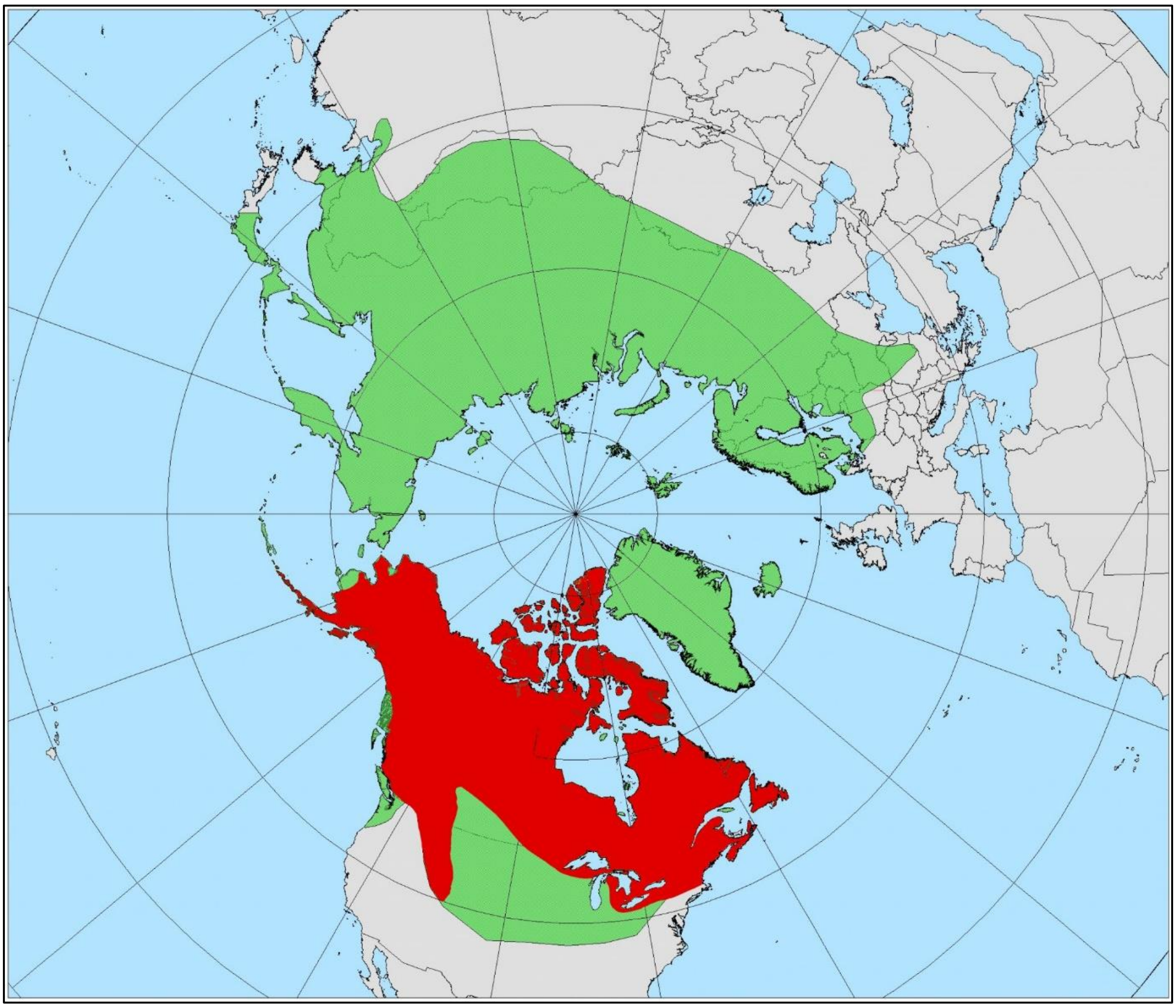

Figure 1 - World distribution of moose (Alces alces).

Source: https://zoosauvage.org

Physiological capacity of breeding is generally reached after one year, but yearling's moose usually do not reproduce, due to the domination by older bulls (Peterson, 1974). Rutting periods take place during autumn, usually between September and mid-October with some variation depending on the living area, and duration of gestation lasts approximately 235 days. As all Cervidae, antlers growth each year before the rutting period, and usually fall in December. Antlers morphology of moose is characteristic, forming palm that makes the difference with the other Cervidae's members, with dendritic antlers.

Herbivorous, moose adapt their diet to the season, the same small amount of species is generally found in the diet, any season included, with a higher level of selectivity during winter (Wam, 2010). In summer, when the vegetation is luxury and plentiful, its diet varies according to the availability of each species. New leaves growing on deciduous trees offer to moose a wide array of nutrients and energy values. Trees species represent more than 50% of the moose's diet, where birch is the most common species found in (Wam, 2010). In winter, when the deciduous vegetation loses its nutritive attraction, moose's metabolism slows down, and it principally lives thanks to the stock accumulated during the growing season. The lack of nutrient full pushes the moose to feed on bark, limbs, and young shoots, especially rowan (*Sorbus sp.*), aspen (*Salix sp.)* or pine (*Pinus sp*.) (Morow, 1976).

In relation to its diet and domination of old bulls, moose adapt their habitat selectivity along the seasons and can easily migrate for dozens of kilometres (Cederlund, 1994). Several authors suggest that this migratory behaviour may be affected by maternal habits, as well as habitat fragmentation or food availability (Cederlund, 1988; Sweanor, 1988). According to Andersen (1991) moose-mother relation during the first autumn is determining in the future winter habitat selection, with margin behaviour for orphans. In general, literature agrees to identify two types of habitat for moose. During the growing season, moose prefer mature forests and open forests without pine, while regeneration forest and pinewood are more used in winter (Nikula, 2004).

Moose's predators are few. If Human is the most significant predators of moose, hunting more than 200,000 animals per year, natural predators can also regulate the population. Wolves and bears are the only natural predators of moose. While bears represent a threat during the growing season, because of overwintering, wolves' pressure is permanent. The success of a hunting wolves' group is generally about 50% and moose takes a big part in their diet (Sand, 2006). To cope with these threats, moose have been adapted their morphology to develop escaping strategies. For example, their long legs allow them to trot over obstacles that force predators to jump over it. In countries with long periods of permanent snow cover, moose adapt their diet and intake rate to decrease energy demand while walking into deep snow (Andersen, 1992).

Moose's footprint is easily distinguishable from other cervid's footprint, especially in North Karelia where only moose and roe deer are found during winter. Its measurements are 16cm length and 13cm width (Fig. 2c), while roe deer's one is 5cm length for 3cm width (Olsen, 2012). Females footprints are generally smaller. Sabots are parallel, not like the reindeer, and side fingers are usually visible in deep snow. Steps are long, with a mean distance of 1.5m between sabots from the same side. When snow is deep and fresh, moose sink to a depth of 20cm, creating typical traces (Fig. 2b) (Lundmark, 2008). Moose's pellets are recognizable from shape and size. Making small heap, dropping generally measures 3cm length for 2cm width. During winter and cold temperatures, droppings are frozen, becoming light and harsh (Fig. 2d).

Figure 2 - a) Moose damage on young pine b) Path made by moose while walking in the snow c) Moose footprint made on the snow d) Moose droppings e) Resting place

Moose in Fennoscandia

Fennoscandia offers more than 1 billion km² of a mosaic forest, and moose occurs both in the three countries. Finnish and Norwegian populations show the same number of animals, 120,000 in 2009, while Sweden is the European country where moose occurs the most, 340,000 animals in 2009 (IUCN, 2015). This high level of population has not been the same over the past year. In the 16th, nobles hunting has pushed moose under a huge pressure, causing extreme decreasing, in terms of number as well as in-home range (Markgren, 1974). However, since Swedish kingdom closed moose's hunting, its population became to growth, and changes in forest management after World War Two have helped moose to find suitable habitat with higher amount of resources.

In Finland, winter moose's stock has doubled from 1996 to 2003, increasing from 66,700 to more than 113,000, representing a mean density of 1 moose / km² (Lavsund, 2003). Nowadays, moose occurs in the whole Finland, with lower density in the north and east. This widespread could be explained by two factors. North Finland, Lapland, does not offer suitable conditions for a sustainable life. Arctic climate does not permit the growth of trees, and both the temperature and insolation are too extreme for its metabolism (Dussault, 2004). In the east, it is not the climate that slows down its expansion, it is even the opposite. Forest cover and climatic conditions offer a suitable area for moose. However, this part of Finland is the only part where wolves and bears are found in wildlife, and therefore, these predators act like regulators (Lavsund, 2003).

Although moose takes an important part in Finnish forestry, it has been labelled as a "harmful species" by the authorities, due to forestry damages and traffic accident (Riistakolmiot, 2019). According to Niemi (2013), 132,330 road accidents with moose have occurred between 1989 and 2011, disturbing the traffic. In forestry, moose usually eat Scots pines (*Pinus sylvestris*) (Fig. 2a) and birches (*Betula sp*.), and can therefore disturb the well-being of forestry system (Ball, 2002)

If small damages are difficult to observe, areas where moose density is high can show a full stand damaged, causing loss of growth rate, or even a full stand loss (Melin, 2016). On contrary, Edenius (1993) found that, in young pine stands, moose browsing could increase the growth of the tree, two years after the browsing damage, but with several impacts on the stand dynamic. The real impacts of moose on forest stands is not commonly defined, and some search and study about its browsing behaviour and selection habitat are still needed.

As forestry is the principal income for Finnish economy (20% of Finnish export revenue), authorities must manage moose's populations to minimize damages. Nowadays, hunting is made locally, with density goal (Lavsund, 2003). Since 2012, more than 30,000 moose are hunted every year, and even more the last two years, with more than 50,000 killed for 2017 and 2018 (Riistahavainnot, 2019). Each hunting localities must fix a stock and structure population to reach during the hunting season, on the basis of estimation given by the research centre of Finnish environment, LUKE (Riistahavainnot, 2019). Proper estimation of population is therefore needed, and different methods are assessed to cope with reality.

3 Estimation’s methods for moose’s populations

Several methods exist to assess moose’s populations. Each of them has its own characteristics, making it suitable for according to the study case. The choice of using one method more than another depends on factors such as management goal, accuracy or financial support. As this study aims to assess the reliability of one of these methods -track counting- it is essential to briefly explain the other main methods used in Finland. Here four methods will be shown: aerial counting, hunter observations, pellet group counting and track counting. However, methods can be led together to reduce cost while keeping a reasonable accuracy (Månsson, 2011b). As track counting is the official method used by the Finnish authorities to assess game population in the whole Finland, its particular principle will be explained in detail.

Aerial counting

Aerial counting is a direct method consisting of linear transects covered by helicopter, generally conducted during winter, when moose’s coat contrasts with the snow (Rönnegård, 2008; Kantar, 2013). Both full inventory or sampling plan can be carried out. Full inventories are conducted by a helicopter covering several transects regularly separated in the whole study area. Sampling method is designed with 2km x 2km plots surveyed by a first helicopter marking all the moose’s GPS positions. A second helicopter covers the plot perpendicularly to mark the remaining moose. However, in the second method, a suitability factor must be added to minimize the errors (see methodology in Rönnegård, 2008; and Kantar, 2013). Advantages of this method are multiple. First, it is a direct measure of species abundance, where every moose is counted, resulting in an absolute value. Second, as Månsson (2011b) shows in his study, standard error is the lowest among the other methods used. For a 1,000 moose population, the mean standard error was 106 individuals. In Maine, USA, study shows the same results for accuracy, with more than 70% of visibility (Kantar, 2013).

If aerial counting seems to be the best and most reliable method to estimate population, some disadvantages slow down its use. Researchers from Washington department of fish and wildlife claim that sightability depends on the forest covers (Harris, 2015). In dense forest cover areas, sightability is generally lower, leading to a bias on the assessment model. Moreover, the most restrictive factor for using aerial count is the cost. In its study,_Månsson (2011b) estimates the total cost at 27,000€ per year, far exceeding the other methods compared.

Aerial counting offers the best method when an accurate number is needed and enables to minimize the errors. However, this method cannot be applied at all scale, due to its huge cost.

Hunters observations

As mentioned above, Finnish hunting system is managed locally. Every hunting district must fix a density goal to reach and give owners the right to kill (Riistakolmiot, 2019). During the first week of hunting season, each hunting group has to count moose observed within the hunting area, resulting in an index, moose seen per hunter per day (Ericsson & Wallin, 1999). As hunter observation is an indirect index, it must be transformed into a real density. Transcription from this index to an absolute value of moose density is generally tricky, and requires linear models (Månsson, 2011b). Relationship models used for transcription are generally found empirically. In their study, Ericsson & Wallin (1999) compared hunter's index to density number from aerial survey to find a relation. Their results were significant, hunter's index and density both reacted the same way. However, the transformation from index to absolute value shows a bigger error than the other methods, aerial and pellet group counting: 146 individuals for a 1,000 moose population (Månsson, 2011b). Some authors even claim that hunter's index does not predict well a moose density (Ueno, 2014).

The main advantage of using this method is the cost. Effectively, it is the cheapest method, with an average of 1,600€ per year (Månsson, 2011b). Even if the index is indirect, hunter's observations are direct, and distinction between male, female, young, adult is easy to collect. Therefore, it can be useful to give the structure of the population, sex ratio or recruitment rate (Solberg, 1999).

However, hunter's observations seem to be more a management tool than a real method to estimate populations (Sylven, 2000).

Even if this index does not give an absolute value of the moose number within an area, its fluctuations between years can be an indicator of the population dynamics (Rönnegård, 2008).

Hunting statistics can also be used to chart a population dynamic, by using animals killed by localities (Ueno, 2014). It is even possible to manage virtual populations, in a software, to observe a potential dynamic, according to different hunting scenarios (Lehtonen, 1998).

Pellet group counting

Moose's pellet group survey is not the most used method to estimate density but offers a good alternative for researchers who do not have enough financial mean (aerial survey) or human resources (hunter's observations) (Härkönen, 1999). Standard procedure is to sample circular plots over the study area and count the number of pellet group in each plot, during the first snow-free days (April-May) (Månsson, 2011a). Plots need to be cleaned every year to be sure that pellet groups counted come from the same season. To be transformed into a density value, it must be supplemented by a study of defecation rate (number of pellet groups per day) (Rönnegård, 2008). A commonly used formula to transcript pellet index to a density is the following one:

$$D = \frac{N/A}{T \times F} \qquad (1).$$

with

D the density (number of animals/km²),

N the number of pellet group counted,

A the total area of the sampling pots,

T the number of days between the cleaning and the counting and

F the defecation rate.

With an estimated cost of 8,400€ and a mean error of 125 per 1000 individuals, pellet groups counting can lead to a reliable estimation (Månsson, 2011b). In China, researchers found that this method gives the most reliable results when surveying Cervids populations (Huapeng, 1997). However, pellet group count method seems to be more a behavioural index than a real method to estimates population number or density, due to the dependency of defecation rate on habitat (Rönnegård, 2008). In its study, Andersen (1992) used pellet group counting to identify individuals and follow their behaviour. Månsson (2011a) demonstrates that the use of pellet group counting could be a good indicator to study moose's winter distribution and habitat selection. Through recent decades, several studies have been widely using this method to assess winter moose or other animals' behaviour (Telfer, 1978; Ollson, 2011; Månsson, 2012).

Track counting

Track counting is probably the easiest indirect method for population estimation, due to its straightforward approach (Keeping, 2014b). Observing animals tracks on any substrates, such as snow, sand or mud, permits to gain several information about the behaviour (track's freshness, meeting point), as well as retracing their movements, without disturbing the animals (Andersen, 1992; Olsson, 1997; Sand, 2006). While following transect, the number of tracks seen is only dependent on the number of animals within the study area and the mean daily distance walked per animal per day (Stephens, 2006; Keeping, 2014a). Thus, by counting the number of tracks along a fixed-length line transect, the Formozov-Malyshev-Pereleshin formula (2) allows the transformation into a density (Formozov, 1932). However, the formula needs an assessment of the daily distance for one individual. This formula allows to minimize errors due to double-count, crossing tracks coming from the same animal.

$$D = \frac{\pi}{2}\frac{X}{S \times M} \qquad (2).$$

With

D the Density (number of animals/km²),

X the number of 24h fresh track counted,

S Length of the transect (km) and

M the daily distance for one individual.

Nowadays, this formula is still used widely in northern countries, especially in Scandinavia (Stephens, 2006; Keeping, 2014a). Some studies in Italia (Romani, 2018), Poland (Checko, 2011), and China (Huapeng, 1997) have been using Formozov-Malyshev-Pereleshin formula to monitor Cervids population. When using track counting method during winter, several conditions are required. First, snow depth must be deep enough to let recognizable tracks (Becker, 1998). Secondly, as snow tracks degrade rapidly, counting must be made quickly to be sure that all footprints counted are 24h fresh (Stephens, 2006). Finally, field observers must be trained to identify perfectly footprints. Species richness within a study area make a vast range of different footprints, and misidentification can easily occur if species footprints are quite similar (Stephens, 2006; Becker, 2015). Glushkov (2013) claims that farther from habitation track counting takes place, more reliable will be the estimation, due to the anthropophobia of moose.

However, the accuracy of this method is not unanimously accepted. Huapeng (1997) shows that track counting method overestimates deer populations in China, and a change in the transect length can affect the results. On the other hand, Romani's study (2018) concludes that track counting leads to a lower density estimation than other methods. Keeping (2014) studied the accuracy of track count on density estimation. He found an overestimation of density in low-productive ecosystems and an underestimation in high-productivity ecosystems, pointing the importance of understanding the relationship between species and their habitat. In addition, choice of the moment to use this method could influence the sightability and the results. In its study, Becker (2015) has performed track counting every day for 42 days, in the same transect. Its results showed a high variance of occurrence, moose being seen only one day, for example. In areas with low density population, the probability of seeing a track along a transect decline, causing errors on the estimation (Kojola, 2014).

Probably the cheapest method among the monitoring methods, track counting offers a simple process for population estimation (Keeping, 2014a). Data are easy to collect and do not demand much financial mean and technical support and enable to estimate populations at a local scale (Glushkov, 2013).

In Finland, track counting method is the official method used by the Finnish Game and Fisheries Research Institute for the survey of all wild animals. As called “Wildlife Triangle Censuses”, 1,600 triangles of 4km strip are randomly located through Finland (Pellikka, 2005). Every year during winter, triangles are covered and the number of tracks for each species is marked, leading to an abundance index (number of track/10km), compared to a kilometric abundance index (Pellikka, 2005). According to a reference (statistics from 1989 to 1994), this index helps the institute to understand better populations dynamics, habitat selection, and fix hunting goal (Pellikka, 2005; Riistakolmiot, 2019.)

4 Electivity indices

When speaking about animal's diet determination, faecal analysis is the most used method, giving good reliability comparing to other methods (Mcinnis, 1983; Shrestha, 2006). However, this method does not take into account the availability of each part of the diets within the environment area. Moose for example will adapt their diet thanks to the forest type surrounding it, as well as the spatial organization (Vivas, 1987). Therefore, in 1961, Ivlev (1961) imagined a formula that compares utilization of a resource to its availability within the environment. Considering r_i, the proportion of a resource food in the utilization (diet), and p_i, the availability of the same resource in the environment, a random selection of this will occurs when $r_i=p_i$. In the case of $r_i>p_i$, resource r_i will be defined as a preferred resource, because of highest representation in utilization than in availability. On the contrary, resource avoiding will be presented when $r_i<p_i$.

The big advantage of its new index was to highlight avoided and preferred resources, according to the proportion of the item in the landscape. Although this index is principally dedicated to diet's determination, it can be easily transposed in habitat selection studies. Effectively, habitat selection and diet answer to both same parameters: utilization and availability (Lechowicz,1982). Nowadays, several indices enable to compare selectivity with availability, they are called "Electivity index". Most popular and used are Ivlev's, Jacob's and Vanderploeg's one, each having its own limits and interpretability. Here a succinct description of these indices will be done.

The first electivity index has been the one proposed by Ivlev in 1961 and focuses only on the resource r_i and its proportion in the environment p_i, without considering other resources (Table 1). In theory, its range goes from a minimum of -1, for a total avoidance to a potential maximum of 1, zero representing a random choice. However, E takes the value of 1 only in unrealistic cases when r_i=100% and $p_i \approx 0$. In Practice, the maximum value that E can reach depends on the availability. Although its approach is simple and coherent, E suffers from two inconveniences. Firstly, a little modification either of r_i or p_i will result in a quick change of E, due to the non-linear deviation model (Lechowicz, 1982). Sampling errors when estimating components of E can rapidly lead to wrong interpretation. Solving this problem necessitates to enlarge the sample, to assure a correct accuracy, even if rare resources will still be difficult to assess (lechowicz, 1982). The second problem is the dependence from relative abundance, that biases the index (Jacobs, 1974). Therefore, in an environment with several resources, E will not have the same maximum limits for each of them, preventing a suitable comparison and interpretation, except if p_i is equally distributed (Lechowicz, 1982; Jacobs, 1974).

Pointing out the weakness of Ivlev's electivity index, Jacobs (1974) proposed a new index that potentially solves it (Table 1). Like E, Jacob's electivity index, D, its range goes from -1 to 1, with the same interpretation. However, it integrates mortality rates of resources type, considering that consuming a resource will reduce its availability (Jacobs, 1974). Therefore, D seems to be less sensitive of sampling errors, and needs smaller samples than E. Despite his effort to build a stronger index, D does not solve the problem of dependencies (Paloheimo, 1979).

It was in 1979 that three authors proposed new and better performing indices. Chesson (1978) first formulated an alternative to the forage ratio (Table 1), based on biological model. Coupled with the study of Vanderploeg (1979), this leads to a normalized forage ratio taking in account r_i and p_i for every resource when calculating the index for one resource (Table 1). In this way, it enables to overcome the problems of independencies. As the index has been normalized, the sum of every W_i for one landscape equals one. The proportion taken by W_i represents its selectivity degrees in the landscape, regarding the other resources. Considering n as the number of available resources, an index of 1/n will represent a random selection, a value below an avoidance, and a value above a preference (Lechowicz, 1982). However, it is still subject to errors for a rare resource leading to a small r_i or p_i (Strauss, 1979).

Based on Chesson's index W, Vanderploeg and Scavia (1979) described an index analogous to the Ivlev's electivity index, E* (Table 1). Their formula is very similar to Ivlev's, but instead of using r_i and p_i, the components are the Chesson's W and the number of resources within the landscape (Table 1). Like E, its range goes from -1 to 1, zero indicates a random selection and 1 that can only be achieved with unrealistic conditions (Lechowicz, 1982). Like W, E* takes into account the selective choice regarding the proportion of the resource compared to those of the other resources (Lechowicz, 1982). Widely admitted in the scientific papers, Chesson's index W and Vanderploeg electivity E* are considered as the best and most efficient electivity indices, although sampling errors can still occur.

Table 1 - Electivity indices equation based on proportion of resources available (r_i) and proportion of resources used (p_i). n is the number of different resources.

Electivity index	Equation
Ivlev electivity	$E = (r_i-p_i)/(r_i+p_i)$
Jacob electivity	$D = (r_i-p_i)/(r_i+p_i-2r_ip_i)$
Vanderploeg electivity	$E^* = (\alpha-1/n)/(\alpha+1/n)$
Chesson's ratio	$\alpha = (r_i/p_i)/\sum(ri/pi)$

These four indices do all have the same objective of representing preference choice of an organism among several resources. They integrate both consumption and availability to determine if there is a clear preference in an organism's diet. However, one common problem still exists in these indices. Tellingly, two different sample plots are comparable only if there are totally the same resources in both environments (Lechowicz, 1982). Therefore, it is challenging to compare organism's diet from two different ecosystems, but it still interesting to focus on local consumption, and eventually its evolution over time.

Despite their defaults, electivity indices are efficient tools for behaviour study, such as diet determination or other resource consumption. In fact, the implementation from these formulae to habitat selection replies to the same postulate of resource availability (p_i, land cover) and utilization (r_i, GPS point). This has been the case in Doerr's study (2005) about winter habitat selection of Sitka black-tailed deer, where several deer have been equipped with radiocollars, to retrace their movements within an environment. These indices can therefore be useful to highlight organism's habitat preference and selection among a panel of different habitats.

5 Goals of the study

In order to understand better moose's behaviour in north Karelia, Finland, and assess moose's impact on forest ecosystem and logging, two aspects are important to take into account. The first one is the estimation of the population within the study area. Knowing the number of animals in an area is primordial concerning impact's evaluation and management (Gasaway, 1986). In this study, focus is made on track count method, and on the evolution of kilometric abundance index during winter. The second one is the Localisation of specific habitat and evaluation of preferred species that may help loggers in forest management.

Evolution of Kilometric Abundance Index

As seen in the literature, the use of track count method for population surveying is widely preferred for large-scale estimation, thanks to its simple approach. Surveys Usually are made once a year, the day depending on the meteorological parameters (Pellikka, 2005). However, Becker (2015) pointed out the representativeness of animal's tracks, showing that doing the same transect on two different days may yield totally divergent results. Furthermore, some literature about the use of this method for moose is missing. This way, it could be interesting to see the evolution of KAI, number of tracks found per 10km, during winter. Meteorological parameters, such as snow depth or temperature, has been already mentioned as factors influencing moose's movements (Lundmark, 2008). However, there is no study about a potential relation between KAI and meteorological parameters. This present study focusses on the evolution of KAI and its relationship with meteorological conditions (temperature, humidity, precipitation, snow depths, snow quality) to answer two key questions:

- How KAI evolve during winter?
- Which meteorological parameter(s) explain(s) KAI well?

Winter habitat selection

Winter habitat has been widely studied for moose, scientific papers converging on similar results. Månsson (2012) shows that pellet groups are more often encountered in low-density pine forests, while other studies preach for a preference of young succession and small trees forest (Mcnicol,1980; Melin, 2013). Although there is a general consensus of studies about the winter habitat, only few of them have shown differences between the preferred habitats and adjacent vegetation. Melin (2013) used GPS locations to identify no-moose areas, in order to highlight height distribution differences from moose areas. However, he stayed focus on height distribution, neglecting other vegetation parameters (species richness, recovery, etc.).

There are generally two types of scales when assessing moose's winter habitat; the large scale (Home range) and the thin one (Habitat selection) (Nikula, 2004). This study clearly focuses on a thin scale and tries to localise local habitat and studies its characteristics in order to anticipate future movements and adapt forest management. Two questions lead this study:

- Where are localised preferred habitats?
- Which are the characteristics of them, regarding contiguous habitat?

6 Materials and Methods

Study area

Localisation

Surveys were conducted in winter, between January and April 2019. The territory where the study took place belongs to the municipality of Lieksa, in North Karelia. It lies at nearly 30 km north from the city of Lieksa and is represented by an ellipse of 25 km long and 10 km wide centred on the coordinate N63 35.266 E30 08.089, running along the Finnish-Russian border (Fig. 3). In Lieksa city, the population density reaches 3 inhabitants per km² but in the study area, this number is largely lower due to the distance from the village's center, as well as urban migration. The study area is crossed by two main roads, mostly used by cars and forestry trucks, as well as several non-snow cleared forest roads.

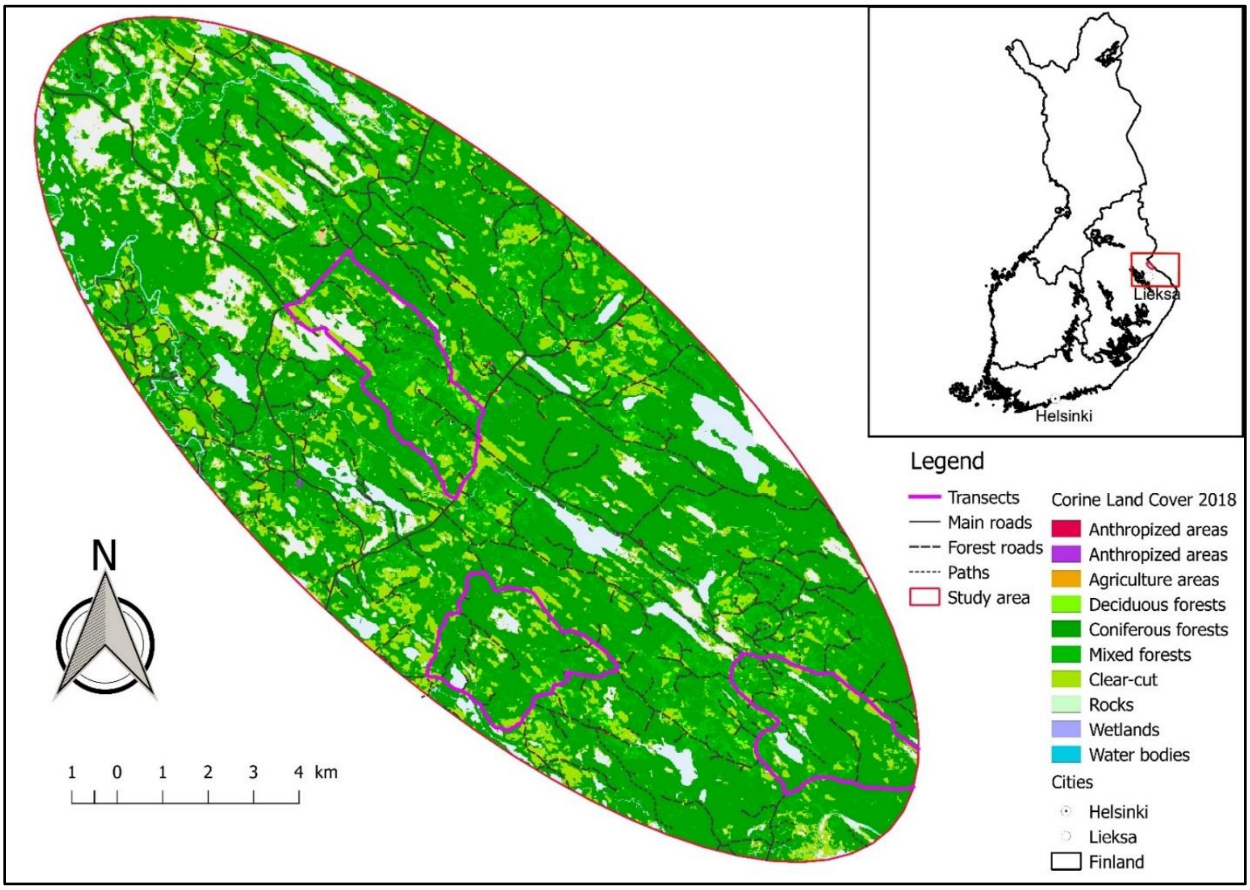

Figure 3 - Study area in mid-east Finland, displaying land cover (Corine Land Cover 2018 data), roads and transects used for Kilometric Abundance Index

Characteristics

The sub-arctic climate within the study area tends to a cold temperate climate, characterized by a mean annual temperature of 1.8° and precipitation of 604mm. Minimum monthly temperatures are reached in January, with -11.7°, while July is the hottest month, with 16.3°. In the study area, there is a permanent snow layer from early December to May, with a maximum snow depth of 1 meter.

Located in the boreal forest, the study area is mostly covered by coniferous stands (Norway spruce *Picea abies* and Scott pine *Pinus sylvestris*), which represents 61% of the total land cover. Generally, spruce stands are found on moist upland sites while pine stands on dry upland sites. Forestry is mainly focused on coniferous even-aged management, with a focus on trees suitability in each soil type (Rentala, 2011). Stand based developments are made with the goal of obtaining the best economic outcome, regarding to the site conditions and requirements that limit trees selections and operation. Deciduous stands are represented by birch (*Betula sp.),* but aspen (*Populus tremula*), willow (*Salix sp.*) and alder (*Alnus sp.*) can be found in young succession. Wetlands, including peatlands, rivers and lakes, reaches 10% of the land cover. Habitations and anthropic constructions represent only 0.25% of the total study area. Undergrowth is not dense when the stands are mature. Logging is made thanks to large cut-overs, creating a mosaic of every forest succession, from open areas to mature forests.

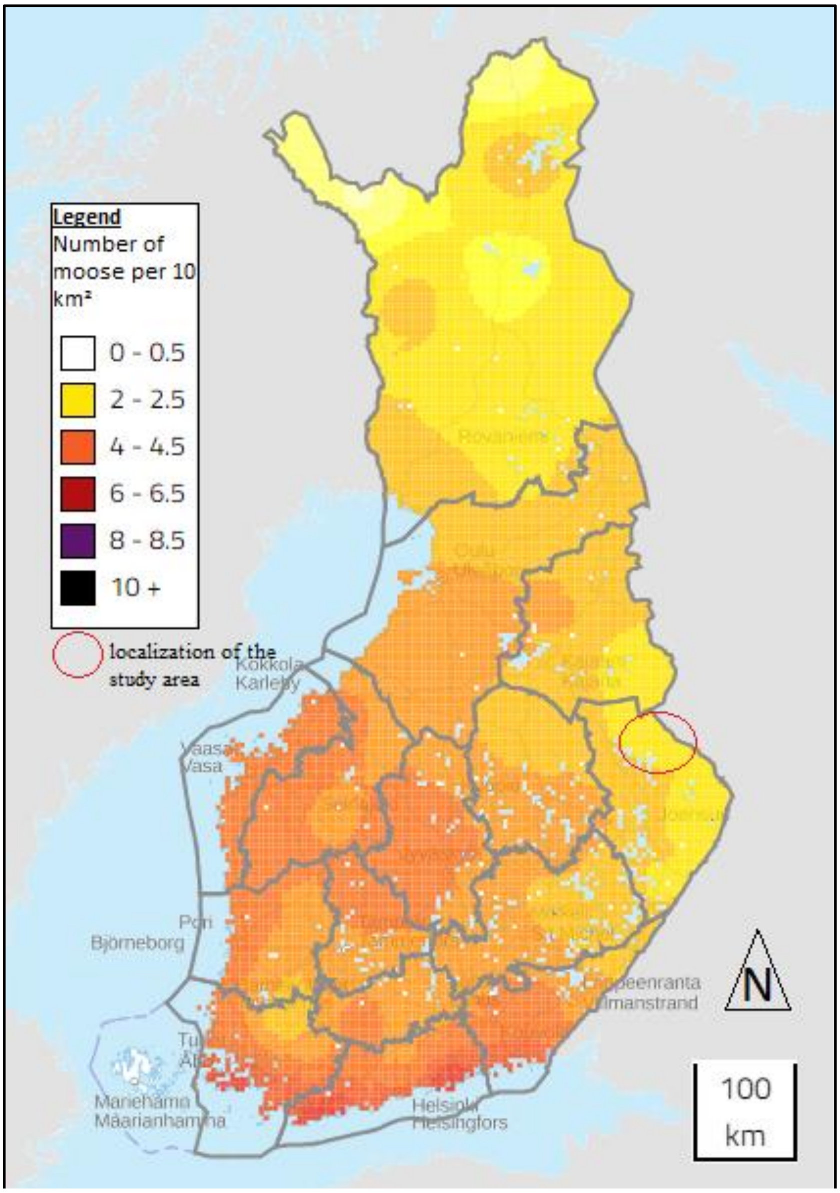

Figure 4 - Map of Finland representing density (moose per 10km²) across the territory, with a pixel accuracy of 10km². Red circle represents the localisation of the study area.

Source : http://riistahavainnot.fi/

Moose in the study area

Moose are surveyed by the Finnish triangle census since 1989, by track counting method (C.F. chapter 3). Between the 1st of January and the end of April, each census triangle scanned only once before calculating the KAI. In North Karelia, daily KAI has never surpassed 7 (tracks seen per 10km per day), with a mean of 4.72 (Riistakolmiot, 2019). It corresponds to a mean population of 14,9000 animals (0.7 animals/km²), within the region since 2008. Moose density in North Karelia is quite similar to the rest of Finland, although highest densities are found in the south-west (Fig. 4).

Study methods

Every day, five meteorological variables were collected from the nearest station, *Lieksa Lampela*, on the official Finnish Meteorological Institute (*https://en.ilmatieteenlaitos.fi*). Only data from the day before were collected:

- Minimal and maximal temperature reached (°c)
- Maximum wind speed reached (m/s)
- Mean atmospheric humidity (%)
- Daily precipitation (mm³)

Other meteorological parameters were daily measured:

- Snow depth (cm): snow depth was measured by using a scale of one meter planted in the ground.
- Snow sinking (cm): snow sinking is collected by throwing a mass of one kilo from one meter to the snow surface and measuring the depth of the sinking.
- Snow hardness: in this study, snow hardness was measured on a scale from 1 to 5, one representing the lowest hardness. A conversion table has been created to associate a number to the hardness (Table 2). In this table, each number corresponds to an empirical criterion, the ease of sinking an object in the snow. If the operator can easily sink his fist into it, the hardness number will be one. Number 2 is given for four fingers, 3 for one finger, 4 for a pencil and 5 for a knife blade.

Table 2 - Conversion table for snow hardness. Each qualitative observation is converted into a code allowing a gradual increasing snow hardness (from 1 to 5).

Fist	Four fingers	One finger	A pencil	A knife blade
1	2	3	4	5

- Snow humidity: as snow hardness, snow humidity was converted into a qualitative variable, in a table from 1 to 5, corresponding to the ease of making snow ball (Table 3).

Table 3 - Conversion table for snow humidity. Each qualitative observation refers to a number code allowing a gradual increasing snow humidity representation (from 1 to 5).

No snowball can be made	The glove stays dry while making a snowball	The glove is wet when making snowball	Water flows from the glove when making snowball	Mix between snow and water in the glove
1	2	3	4	5

Kilometric Abundance Index

Data gathering

To estimate KIA, three transects have been randomly dimensioned within the study area, each of them making a loop crossing several biotope types. Transect's distances are respectively 12.5km, 13.4km, and 15.5km (Fig. 3). Between 22rd January 2019 and 23nd April 2019, transects were weekly walked and every new moose's track crossing the transect has been geolocated with a GPS (Garmin eTrex 10). In the case of a track following the transect on several meters, or if two tracks were observed to come from only one individual, it will be count as only one track.

Afterward, transects data were sorted by date and number of transect, and mean daily KIA are estimated by comparing the number of tracks seen and the number of days with the precedent transect:

$$KAI = \frac{\frac{n}{k} * 10}{d} \qquad (3).$$

With n, the number of tracks seen during the transect, k, the distance of the transect and d, the number of days with the precedent transect.

Analysis

All analysis for KAI was made using R software with package lmtest and leaps. To see how KAI evolves according to meteorological variables, linear regressions were made with each variable separately. For each model, r^2 was studied, to select the models that explain most of the variation. Afterward, best subset method was computed to select the three best models comparing KAI to several meteorological variables. This method explores the whole possibility of combination to compare them in terms of several parameters; r^2, adjusted r^2, BIC (Bayesian Information Criterion). R^2 and adjusted r^2 are coefficients that determine how the model predicts the variation of the dependent variable, according to the dependent variables of the model. Its range goes from 0 to 1, 1 corresponding to a full variation prediction. BIC (Bayesian Information Criterion) measure the bias of the model's prediction. A model is considered good when the r^2 is optimized, regarding to the number of predictors, and the BIC is minimized. In this study, the three models presenting the best r^2, comparing the number of parameters, and the lowest BIC, were selected to go deeper in the regression analysis. For each model, lmtest was computed to shows the coefficient of each parameter, Anova table of the regression and summary table for the model.

Snow humidity and snow hardness being qualitative factors, two-way Anova was so conducted to observe a potential interaction between these factors and KAI. If Interactions between factors are observed, two one-way Anova were computed, one for each factor. For a significant difference, mean structuration was made using Newman & Keuls method, to separate means by their group.

Winter habitat selection

Data gathering

Freshest tracks found during transect realisation were followed the next day, and preferably backward, to avoid animal's disturbance. Trackings were recorded by using a GPS (Garmin e-trex 10) that saves points at regular intervals (10 min), before connecting them with each other. During the track, every pellet groups (Fig. 2d) and resting places (Fig. 2e) on the way were GPS-marked, with a specification to distinguish them. Description of droppings have been made in chapter 2. If several moose are followed (a mother and its offspring for example), number of droppings or resting place are specified on commentary when marking a GPS-point. Tracking is stopped for three different reasons. First if the tracks are no longer visible, like a moose crossing a road for example. Second if, by following frontward the tracks, animals are too close, and tracks of running are found. Finally, the third reason is when the track joins others, making no tracks clearly distinctive. For the third reason, a GPS-point is marked, specifying a huge number of fresh tracks found.

For each tracking, its distance, number of individuals followed and number of found items (droppings and resting place), have been listed on a worksheet. GPS-data were saved on a geodatabase file specifying the date of the tracking, *tracking_yyyyddmm.GDB*, including the tracks and the different GPS points linked to the found items.

Moose distribution across the study area

In order to localise preferred habitats within the study area, GPS points of droppings and resting places were imported in Qgis software, using *ETRS-TM35FIN* projection. Heatmap has been computed thanks to Heatmap Qgis extension. This function allows to show high-density places of found items. From shape layer, it uses influence ray and core shape. As this study focuses on winter habitat selection, more weight has been given to resting place points. Effectively, resting places represent better how moose select habitat, even if Månsson (2012) shows that the use of pellet group counting method to estimate habitat selection gives similar results, and other studies used it (Härkönen, 1999.).

From the created heatmap, high-density zones were selected to determine selectivity by electivity indices described in chapter 4. By using 2018 Corine Land Cover data and Lecos Extension on Qgis, proportions of each land cover were calculated, both for the study area and the high-density zones. On one hand, Corine Land Cover is a European project started in 1985 that aims to provide precise information about land use. Data are derived from satellites images interpretation and allow an accuracy of 25 hectares. Land use is divided into 5 big groups: Anthropized zone, Agriculture, Forest, Wetland, and Waterbodies. On the other hand, Lecos Qgis extension gives a function that calculates the area of each different pixel type on a raster layer. Then, it is possible to transform it into a percentage index. After the proportion's calculation, electivity indices have been calculated, Ivlev, Jacobs, Chesson and Vanderploeg (Table 1, in chapter 4). Electivity indices will give information about avoidance/preference behaviour according to each land cover.

Characterization of preferred habitats

To analyse winter habitat characteristics, a quadrat method has been implemented. As moose take rest approximately one time per 24h, locations where more than three close resting places are considered as a preferred habitat. Resting places used for localisation were derived from those found during tracks. For each of these locations, sampling plots of 5m x 5m have been randomly positioned: one within the preferred habitat, and 4 in adjacent habitats. The goal is to identify differences between these two categories and show which characteristics are significant in the winter habitat selection. Adjacent habitats are place situated at more than 50m from the found resting places. For each quadrat, vegetation characteristics have been measured, and divided according to the shrub layer (0-4m) and trees layer (4m and more):

- Absolute species richness (number of species)
- Number of individuals per species
- Height of the 5 tallest individuals per species
- Braun-Blanket covering

For the last characteristics -Braun-Blanket covering- table 4 shows the transcription from percentage to figure's code. Same data are collected for both preferredl habitats and adjacent habitats. In the end, it makes eight vegetation characteristics to measure for each quadrat.

Table 4 - Braun-Blanket conversion table in order to convert percentage of covering into a number code. number 0 represents the lowest possible covering (à%) while code 6 represents the highest range of covering (75-100%).

0%	1%	1-5 %	5-25 %	25-50%	50-75 %	75-100 %
0	1	2	3	4	5	6

As one of the goals of this study is to assess characteristics of winter habitat, compared to adjacent vegetations, one-way Anova has been carried out for each of the eight characteristics with habitat type (preferred or adjacent) as the only factor. In addition, species richness indices (Shannon and Simpson) were calculated for each layer. Shannon index generally varies between 0 and 5, although values more than 5 can eventually be reached. It measures the diversity within a group of surveys (plant or animal), and a low value refers to a low degree of diversity. On contrary, Simpson index is an index varying from 0 to 1. This last index measures the probability for two individuals randomly selected from one sampling to come from two different species. A Simpson index below 0.5 means that there is more than 50% chance that two individuals randomly selected come from the same species. One-way Anova were also proceeded for diversity indices. All analyses have been realised thanks to R package lmtest, vegan.

7 Results

Weather conditions

In total, the period of data gathering lasted 92 days, from 22 January 2019 to 23 April 2019. Mean daily temperature has gone from -22.1°c for the first day of the experiment to 8.65°c for the last day (I.E. the hottest day), resulting in an absolute gap of 30.75°c. Temperature has globally increased during the experiment. January's mean temperature was -19.56°c while following month were gradually warmer (February: -6.6°c, March: -3.8°c, April: +2.3°c) (Fig. 5). The mean coldest day was recorded on 24 January, with an average temperature of -27.25°c. The coldest and hottest recorded temperature was -34.4°c on 28 January and 17.2°c on 23 April (Table 5).

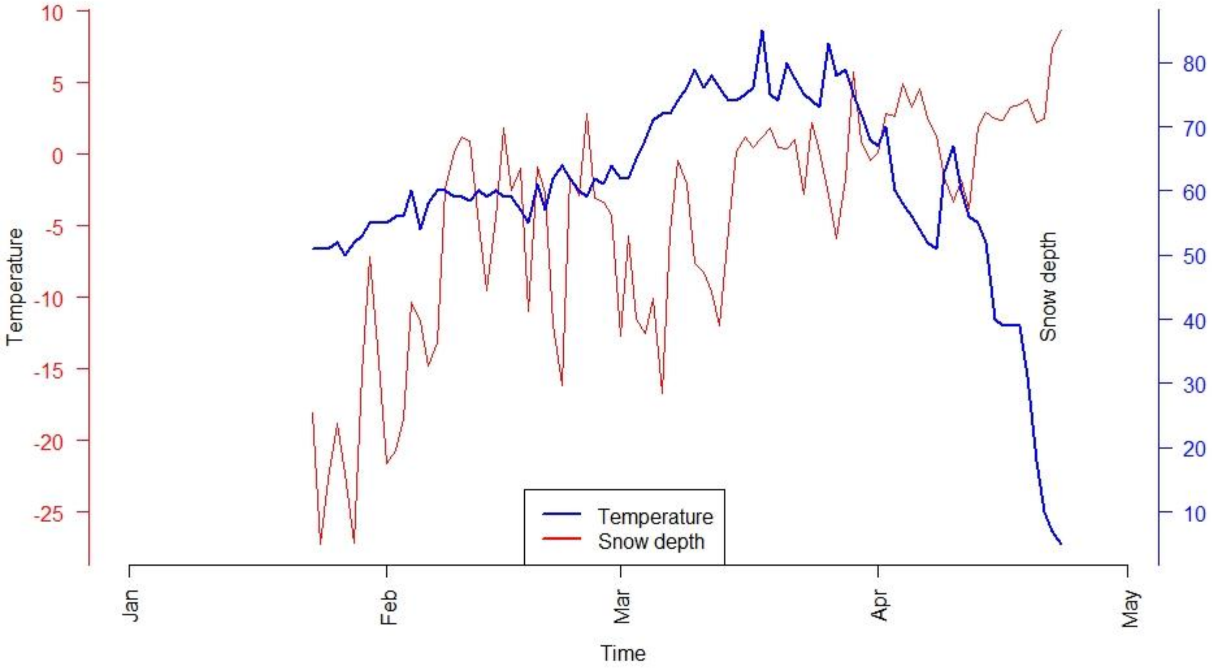

Figure 5 - Evolution of mean daily temperature (in red) and snow depth (in blue) during the study. Minimum and maximum mean daily temperature reached was respectively -27.25°c (24th of January) and 8.65°c (23rd of April). Maximum snow depth reached was 85cm (18th of March).

Snow depth has varied between 5cm (23 April) and 85cm (18 march), with 88 following days of 30cm or more snow depths, and 83 of 50cm or more (Fig. 5). March was the snowiest month, with a total precipitation of 43.4mm. February month was similar to March, 40.8mm. January and April have recorded a total precipitation of 11mm and 17.3mm respectively. 2 March was the snowiest day, with 11.2mm fallen during 24h. on 92 experiment's days, it did not snow for 42 days.

Mean snow sinking, which represents the sinking depths while throwing a one-kilo mass at one meter from the snow surface, is 11.21cm, but knows some variation. Atmospheric humidity has never fallen under 49% with 31 days of 90% or more humidity. Maximum reached windspeed was 12m/s, reached once on 17 February. Extreme Values, medians and means are described for each variable in table 5.

Table 5 - Statistical parameters for each recorded meteorological variable (Extreme values, median and mean).

Variable	Minimum	Maximum	Median	Mean
Minimal temperature (°c)	-34.40	4.00	-6.70	-9.71 ± *9.36*
Maximal temperature (°c)	-2270	17.20	1.75	-0.02 ± *7.96*
Mean daily temperature (°c)	-27.25	8.65	-2.45	-4.86 ± *8.33*
Daily temperature gap (°c)	1.30	22.30	9.55	9.69 ± *4.91*
Precipitation (mm)	0.00	11.20	0.15	1.22 ± *2.17*
Wind speed (m/s)	0.00	12.00	5.00	5.20 ± *2.28*
Atmospheric humidity (%)	49.00	100.00	84.00	80.65 ± *13.85*
Snow depth (cm)	5.00	85.00	60.00	59.96 ± *15.29*
Snow sinking (cm)	2.00	30.00	10.00	11.22 ± *6.33*

Concerning qualitative data, snow hardness and snow humidity, these were also daily recorded. Snow hardness goes from 1 for a powdery snow to 5 for a hard snow. Snow has never reached the maximum value, with a high representation in class 1 and 3 (Table 6). Snow humidity is also coded from 1 (dry) to 5 (wet). Never above code 3, days are equally represented into the classes (Table 6).

Table 6 - Repartition of frequency for snow hardness and snow humidity (number of days presenting the code). Even if the code does not refer to the similar qualitative observation, as the range is the same, frequency is shown in the same table.

Code	Snow hardness	Snow humidity
1	65	42
2	10	20
3	15	30
4	2	0
5	0	0

Evolution of Kilometric Abundance Index

Global results

Transect 1 has been carried out 13 times from 22/01 to 18/04, second transect 11 times from 31/01 to 23/04 and third transect 10 times from 11/02 to 16/04, 434 odd km have been covered. The maximum gap between two same transect's realisation never exceeds 8 days. 191 GPS points have been marked and 266 moose's tracks found during the whole experiment. 110 tracks have been found on transect one, 135 on transect two and 21 on transect three (See table). Based on total results 6.1 footprints were seen per 10 km, resulting in a moose density of 1.12 individuals per km², considering moose daily distance of 850 meters (equation 2 in chapter 3). However, this result varies when focusing on each transect (Table 7). Only transects two and three show a significant difference, where more footprints were found on transect 2 (p-value = 0.0057). Results of transect one are considered similar to both transect two and transect three. Maximum number of tracks seen during one transect's realisation is 37 for and minimum is 0.

Table 7 - Collected data for each transect. Table shows number of realisations, total number of tracks found during the whole study and extreme values for a single realisation.

Transect number	**1**	**2**	**3**
Realisation	12	10	9
Total number of tracks found	110	135	21
Maximum tracks found in one realisation	18	37	7
Minimum tracks found in one realisation	2	5	0
Average tracks per realisation	9.17 ± *5.57*	13.50 ± *11.06*	2.33 ± *2.65*

Daily measured KAI globally decreased over the winter, with some up and down, going from an index of 1.47 to 0.4 (Fig. 6). On average, 0.9 footprints/10km were seen every day (moose density of 0.16 individuals per km²). Maximum KAI was observed between 1 and 5 February (2.53 footprints/10km), resulting in a moose density of 0.46 moose per km². Minimum KAI was observed between 9 and 16 April (0.21 footprints/10km), resulting in a moose density of 0.04 moose per km².

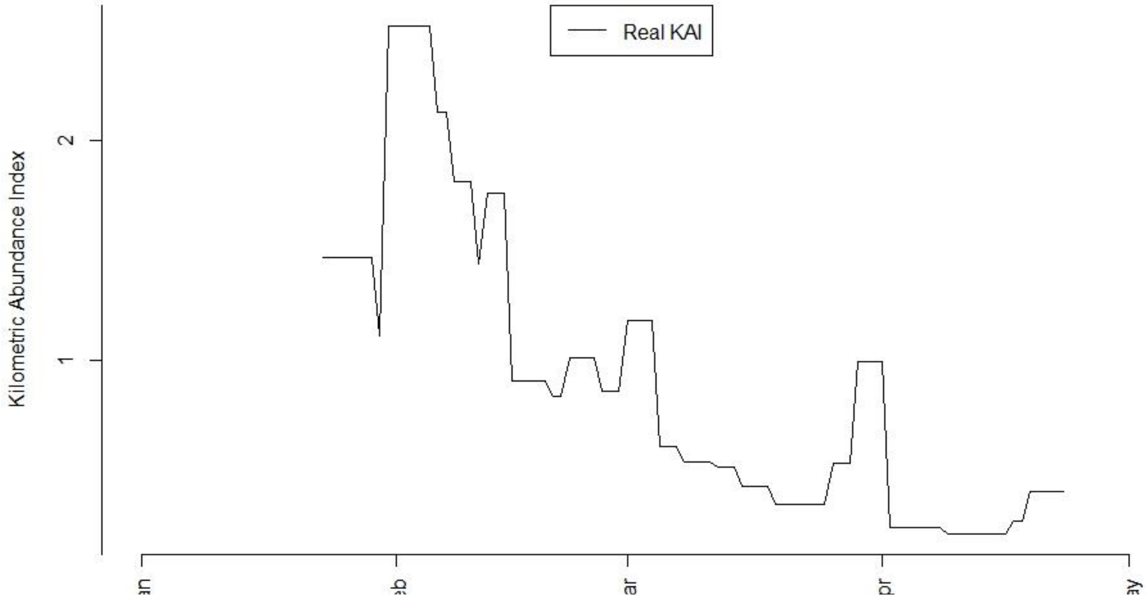

Figure 6 - Evolution of Kilometric Abundance Index (number of tracks seen per 10km per day) during the study. Highest KAI was 2.53 while minimum KAI was 0.21.

Two-way Anova analysis (snow humidity and snow hardness) shows no interaction between these two factors. One-way Anova has shown a significant difference of KAI for both snow humidity (p-value=1.1e-11) and snow hardness (p-value=0.000237). The structuring of averages by the Newman & Keuls method for the first factor gives three distinct groups. KAI is higher when snow humidity is 1 (1.34±0.45) than for a snow humidity of 3 (0.33±0.02). KAI for snow humidity of 2 fits between the two means (0.86±0.2). The same structuring for the second factor shows first significant group of KAI values when snow hardness is 2 or 4 (0.49±0.36 and 0.21±0) and another group for a snow hardness of 1 (1.11±0.68). For a snow hardness of 3, KAI can be considered both as similar to the two groups of means (0.44±0.28).

When studying the individual effect of each variable on KAI, it evolves in different ways (Fig 7). KAI seems to be not influenced by daily temperature gap, daily precipitation and snow depth (Fig. 7 a, e, g). For the remaining variables, there are two groups of influence. On one hand, KAI increase with an increasing sinking depth and atmospheric humidity (Fig. 7 b, i). On the other hand, it decreases with an increasing of all temperature variables (daily maximal and minimal temperature, mean daily temperature) and daily maximum windspeed (Fig. 7 c, d, f, h).

Individual linear regressions show that snow sinking is the variable that explains the best the variation for predicting KAI, with a R-squared of 0.45 (Fig. 7 b). As R-squared of several variables reaches similar values, such as temperature (mean, daily maximum and daily minimum), combinations of variables may increase the accuracy of prediction. Therefore, the use of best subset method gives a quick information about parameters of each possible combination.

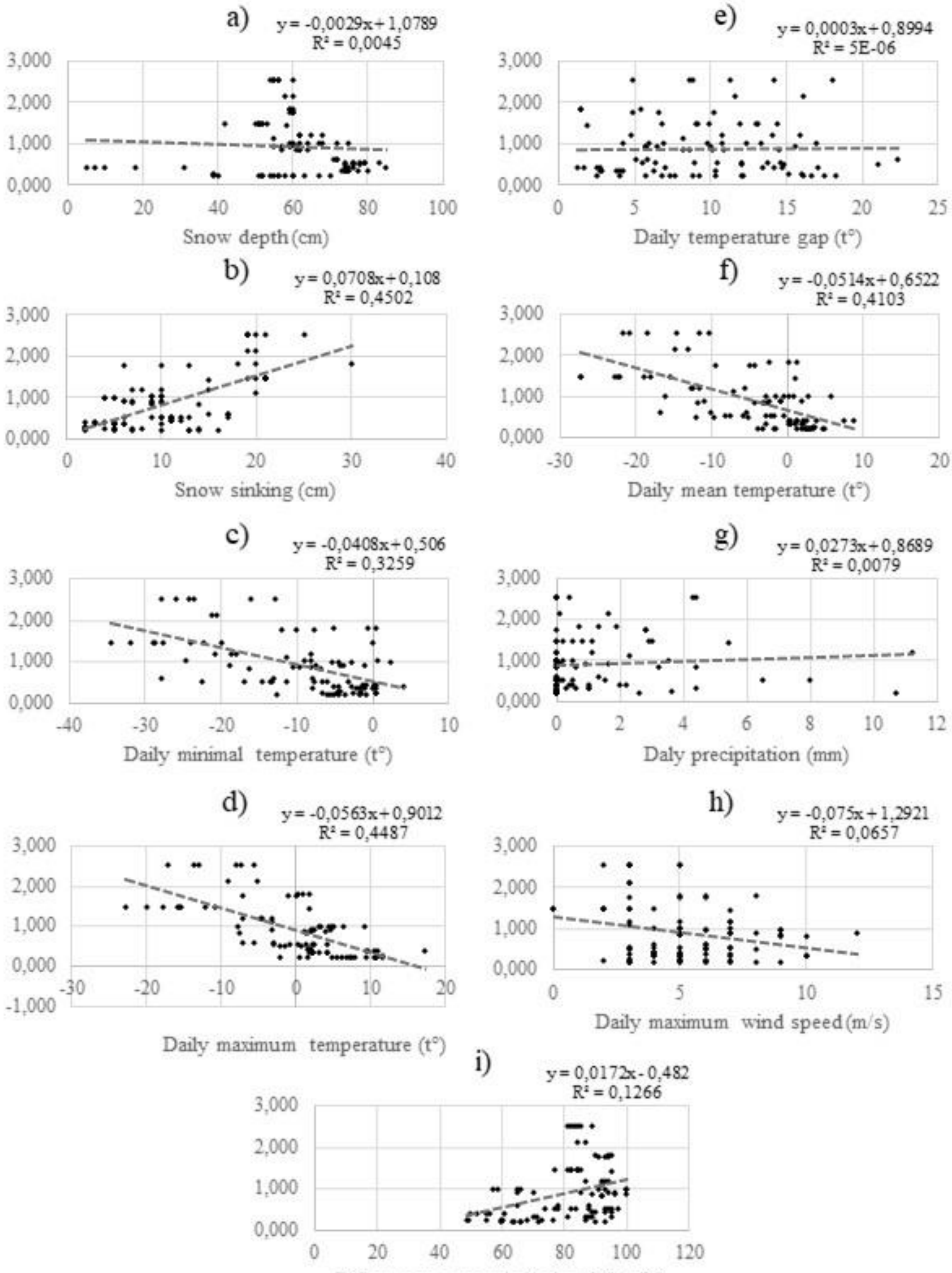

Figure 7 - Linear regressions between Kilometric Abundance Index (number of tracks seen per 10km per day) and each meteorological variable. Every regression is completed with equation and r². Meteorological variables are: a) snow depth, b) snow sinking, c) daily minimal temperature, d) daily maximum temperature, e) daily temperature gap, e) daily mean temperature, g) daily precipitation, h) daily maximum wind speed, i) daily mean atmospheric humidity.

Multiple regression and model building

Table 8 shows the results of Bestsubset when considering combinations of variables. The three models that optimize the best both r-squared and BIC were retained for deeper analysis: (1) snow depth + snow sinking + maximum temperature + mean temperature, (2) snow depth + snow sinking + maximum temperature + atmospheric humidity, (3) snow depth + snow sinking+ maximum temperature. Indicators for these three models are similar, each of them explaining a little bit more than 50% of the variation.

Table 8 - Results of bestsubset method in order to compare each model for Kilometric abundance Index prediction. r² and Bayesian Information Criterion (BIC) allows a selection of models that maximize the first index and minimize the second one. The three underlined models are the selected ones. SD=snow depth, SS=snow sinking, MAT=maximum temperature, MIT=minimal temperature, T=mean temperature, TG=temperature gap, P=precipitation, H=humidity, W=wind speed.

Model	**r²**	**BIC**
SS + T	0.51	-53
SS + MAT	0.51	-53
SS + W	0.51	-52
SS + MIT	0.5	-49
SS + P + W	0.52	-48
SD + SS + W	0.53	-47
SD + SS + T	0.53	-51
SD + SS + MAT	0.54	-54
SD + SS + MAT + W	0.55	-51
SD + SS + MAT + H	0.55	-52
SD + SS + MAT + TG	0.55	-51
SD + SS + MAT + T	0.55	-52
SD + SS + MAT + W + H	0.56	-49
SD + SS + MAT + P +H	0.56	-47
SD + SS + MAT + TG + T	0.56	-49
SD + SS + MAT + H + T	0.56	-47
SD + SS + MIT + MAT + T + TG + H	0.57	-40
SD + SS + MIT + T + TG + P + H	0.57	-40
SD + SS + MIT + T + TG + W + H	0.57	-40
SD + SS + MAT + T + TG + H	0.57	-44
SD + SS + MIT + T +TG + P	0.56	-44

After lm procedure of R software, only model three gives significant p-values for all coefficient composing it (Table 9). Those p-value allow to conclude if the coefficient is significantly different from zero. Therefore, model three has been retained to be the one which explains the best the evolution of KAI according to meteorological parameters. Prediction from this model on the dataset shows a mean absolute difference of 0.37 (±0.26) with a maximum difference between the real and predicted KAI of 1.03 (Fig. 8). According to the selected model, KAI's evolution is proportional to an increasing sinking depth and anti-proportional to an increasing snow depth and daily maximal temperature (Table 9).

*Table 9 - Representation of each selected model predicting KAI. Equation with intercept is written, as well as p-value signification (*** for <0.001, ** for <<0.01, * for <0.05, . for >0.5) for every parameter included in the model. SD=snow depth, SS=snow sinking, MAT=maximum temperature, H=humidity, T=mean temperature, I=intercept of model's equation.*

			p-value					
Model	**I**	**Equation**	**I**	**SD**	**SS**	**MAT**	**T**	**H**
SD + SS + MAT	*0,0953*	*-0,008098xSD + 0,039213xSS - 0,037084XMAT*	***	*	***	***		
SD + SS + MAT + H	*0,63515*	*-0,010371xSD + 0,035173xSS - 0,035393xMAT + 0,006192xH*	.	**	**	***		.
SD + SS + MAT + T	*0,99518*	*- 0,008349 + 0,038747xSS - 0,041963xMAT + 0,004525xT*	**	*	**	.	.	

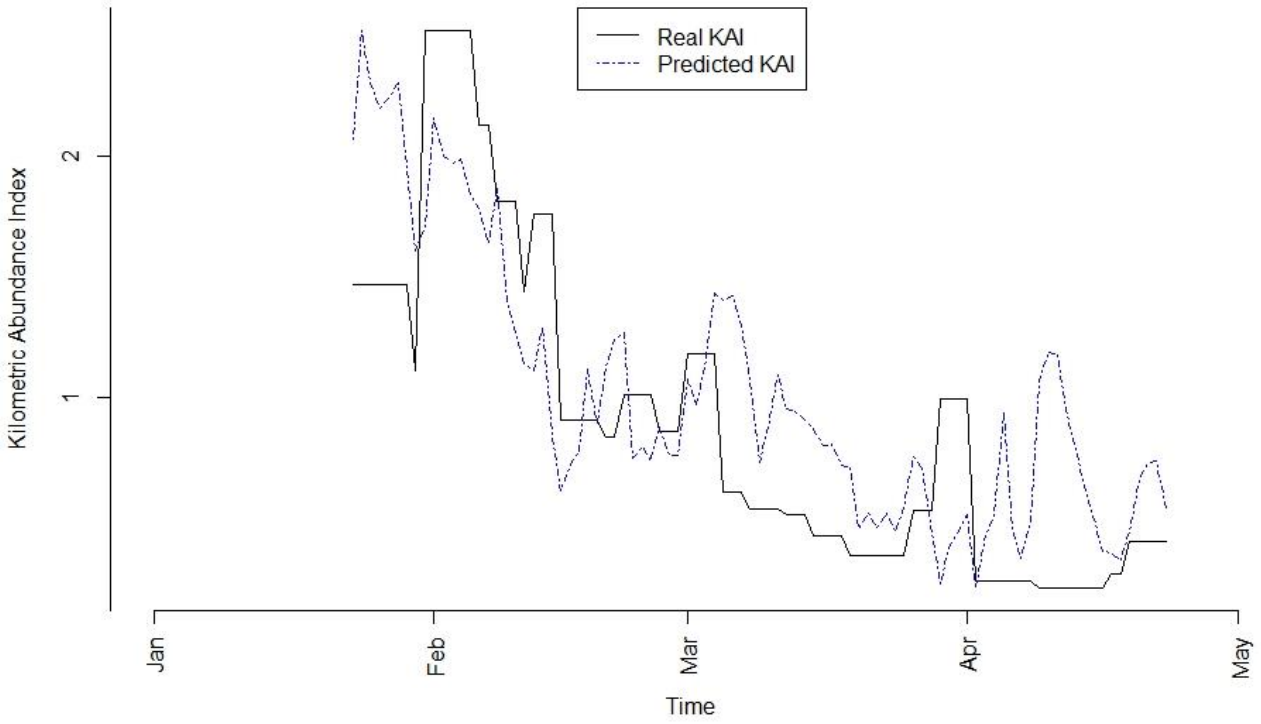

Figure 8 - Comparison between real Kilometric Abundance index (in black) and predictions from the model (in blue). Selected model for these predictions includes snow depth (SD), snow sinking (SS) and maximum temperature (MAT) :0.0953 - 0.00809xSD+0.039213xSS-0.037084xMAT (r^2= 0.54).

Winter habitat Selection

Global results

On the 266 tracks found during transect's realisation, 74 tracks were followed, for a total tracking distance of 70 odd km. 248 Resting and 256 droppings places have been found, resulting in 380 GPS points. 161 GPS points correspond to a resting place presence and 244 for a dropping presence. A same GSP point can include both a presence of resting places and droppings (24 GPS points). Most of the time, resting places are found alone or in pair of two, similar to droppings (Table 10). Maximum resting places found in one tracking is 30 for a distance covered of 3.9km. Maximum droppings found in one tracking is 37 for a distance covered of 2km. On average, there is a resting place area every 430 meters, while dropping occurs every 290 meters.

Table 10 - Frequency of found items (droppings and resting place) during tracks realisations. Furnished numbers give the frequency of gathered items when they were founds. For example, number 16 means that 16 times two resting places were found together.

	Frequency of found items	
Number	**Resting places**	**Droppings**
0	164	262
1	262	125
2	16	31
3	3	26
4	2	2
5	0	0
6	0	1

Heatmap and electivity indices

Heatmap was processed using the 380 GPS points marked during trackings. Figure 9 shows the study area with the heatmap representing the density of GPS points. Gradual coloration of heatmap corresponds to an increasing density of GPS points. Places outside this heatmap have not been characterized by a presence of droppings or resting places. Heatmap covers about 101 km² of the 194 km² study area (52%). Surface covered by zones with highest density of GPS points is about 2.1 km².

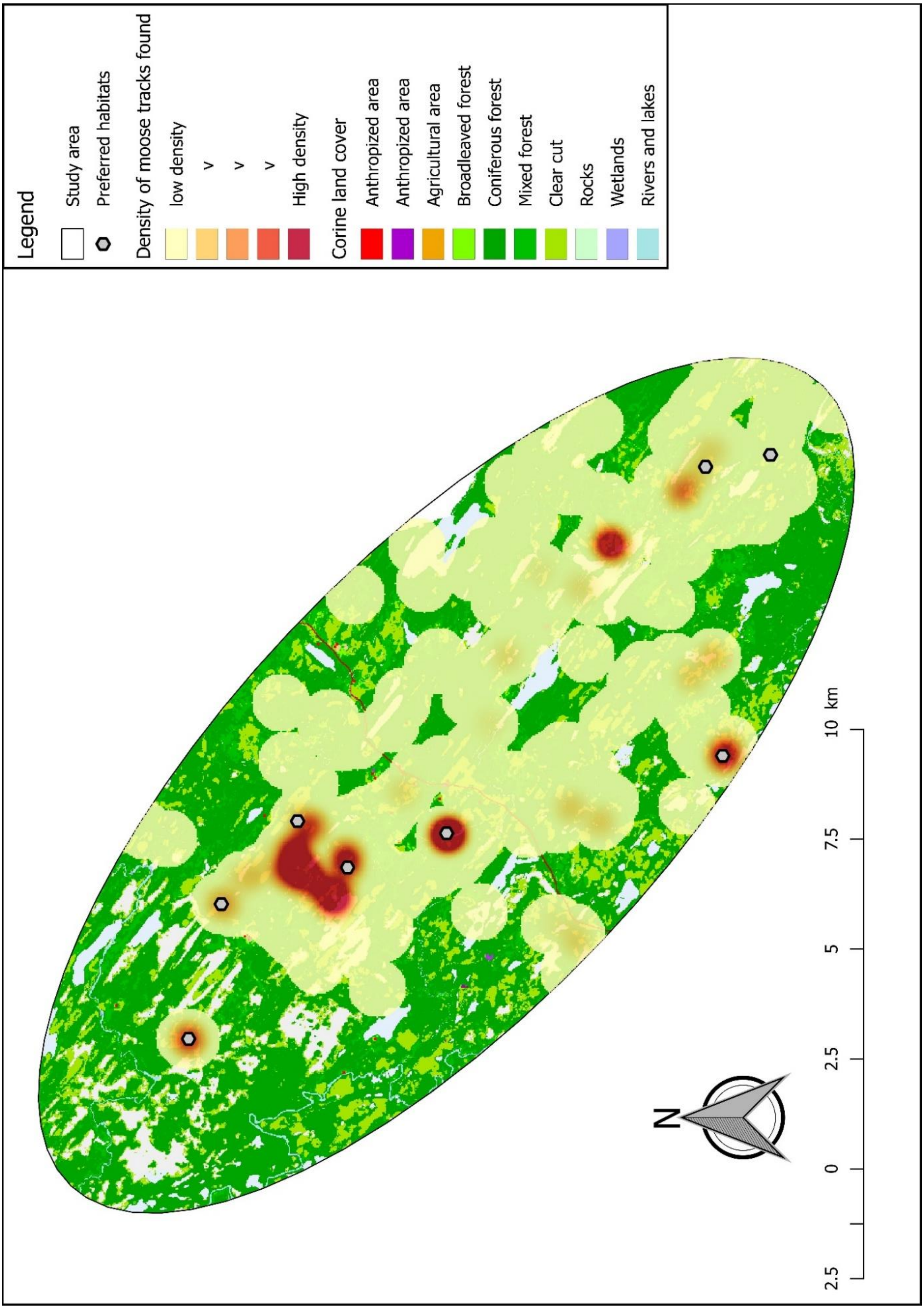

Figure 9 - Heatmap of study area showing zones with high density of found items (droppings and resting place) thanks to Heatmap extension of Qgis. Pixels have bigger density value from yellow to red. Localisation of selected preferred habitats for quadrats method is also shown.

Figure 10a shows the proportion of each land-cover, according to 2018's data of Corine Land-Cover. Coniferous forests cover more than half of the study area, and 40% are coniferous stands on mineral soil. On the 27 land-cover existing in the study area, Red zones (I.E. zones with high density of GPS points) occur on 13 habitats, 65% are found in coniferous forests (Figure 10 b). When focusing on Chesson's index, which is a utilization ratio according to availability of every existing habitats, clear-cut with regeneration emerges as the main selected habitat, in front of forest stands on peatland (Mixed and Coniferous) (Figure 10 c).

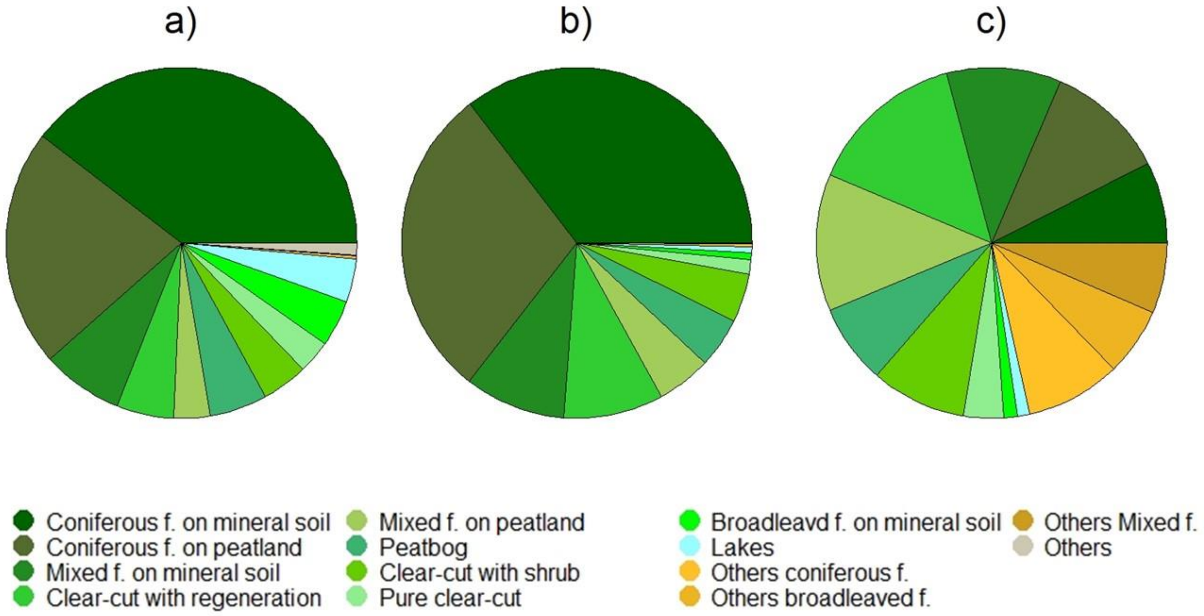

Figure 10 - Pie chart representing a) proportion of available habitats in the study area, b) proportion of used habitats c) Chesson's ratio. Data used for b) and c) come from superficies of zones with high density of found items (droppings and resting place). Habitats names and proportions come from Corine Land Cover 2018 data.

Habitats within Red zones have been submitted to the electivity indices (Table 11). Clear-cut areas with regeneration take the highest value for each index. The following values come from mixed forests on peatland and coniferous forests on peatland. Although Vanderploeg's electivity index states a preference for some land-cover, instead of an avoidance highlighted by the other indices, ranking of preferred habitats remains the same, only Jacob's index switches peatbogs and coniferous forests on mineral soil (Table 11).

Table 11 - Electivity indices (Ivlev, Jacob and Vanderploeg) calculated from zones with high density of geo-localised items (droppings and resting place).

	Ivlev electivity	**Jacob electivity**	**Vanderploeg electivity**
Clear-cut with regenerations	0.2662	0.2854	0.5925
Mixed f. on peatland	0.2035	0.2119	0.5477
Coniferous f. on peatland	0.1378	0.1837	0.4986
Mixed f. on mineral soil	0.1153	0.1258	0.4812
Clear-cut with shrub layer	0.0239	0.0250	0.4076
Other coniferous f.	0.0202	0.0203	0.4045
Coniferous f. on mineral soil	-0.0548	-0.0876	0.3398
Peatbogs	-0.0689	-0.0725	0.3273
Other mixed f.	-0.1257	-0.1257	0.2751
Other broadleaved f.	-0.1454	-0.1455	0.2565
Clear-cut	-0.3914	-0.3988	-0.0047
Broadleaved f. on mineral soil	-0.7378	-0.7463	-0.4906
Lakes	-0.7611	-0.7684	-0.5299
Habitations	-1.0	-1.0	-1.0
Habitations	-1.0	-1.0	-1.0
Habitations	-1.0	-1.0	-1.0
Industrial areas	-1.0	-1.0	-1.0
Zone service	-1.0	-1.0	-1.0
EXTRACTION SOL	-1.0	-1.0	-1.0
Leisure area	-1.0	-1.0	-1.0
CHAMPS	-1.0	-1.0	-1.0
Agricultural areas	-1.0	-1.0	-1.0
COUPES autres	-1.0	-1.0	-1.0
Rocks	-1.0	-1.0	-1.0
Wetland areas entry	-1.0	-1.0	-1.0
Wetland areas exit	-1.0	-1.0	-1.0
Rivers	-1.0	-1.0	-1.0

Quadrats results

Eight places with more than three close resting places have been found during the trackings (Fig. 9). These places have not all been found in zones with high density of resting places because of the selection criterion of Heatmap Qgis extension. Effectively, preferred habitats can be considered if there are at least three close resting places. However, they can occur in areas with a low density of resting places, isolated from high density zones.

41 surveys have been made, 11 inside these places, and 30 in nearby vegetation. Three species have been found in the tree's layer (*Picea Abies*, *Pinus sylvestris*, *Betula sp.*). The same species added up to three others (*Salix sp., Sorbus sp., Populus sp.*), have been inventoried in the shrub's layer.

One-way Anova on tree layer shows a significant difference in species richness, number of individuals and covering (Table 12). On the 11 surveys inside the preferred habitats, 5 of them are characterized by an absence of tree and only two surveys in nearby vegetation show this result. Tree's species richness is higher in adjacent vegetation (p-value=0.0182). More trees are counted in these areas (p-value=0.033). Mean height of trees in preferred habitats (11.76 m±4.55) is not significantly different (than in adjacent zones (11.19m±4.19). For the both zones, *Pinus sylvestris* is the most present species in tree layer, followed by *Betula sp.* then *Picea abies* (Table 13).

Table 12 - One-way Anova results for each variable. Anova is made to observe differences in variables between preferred habitats and adjacent vegetation. Significant difference is concluded when p-value<0.05.

	Mean		
Variable	**preferred habitats**	**Adjacent vegetation**	**p-value**
Tree layer			
height	11.76 ± *4.55*	11.19 ± *4.19*	0.786
species richness	0.72 ± *1*	1.4 ± *0.67*	0.0182
number	2.54 ± *3.42*	5.33 ± *3.63*	0.033
Covering	2 ± *2.37*	4.2 ± *1.51*	0.000795
Shrub layer			
height	1.66 ± *0.43*	1.59 ± *0.68*	0.773
species richness	1.63 ± *0.92*	1.63 ± *1.1*	0.994
number	16.36 ± *13.02*	9.27 ± *8.29*	0.045
Covering	3.45 ± *1.69*	3 ± *1.58*	0.427

When focusing on shrub layer, only the number of individuals (all species included) counted is significantly different between surveys (Table 12). With a p-value of 0.045, there are more individuals in preferred habitats (16.36±13.02) than in nearby vegetation (9.27±8.29). In shrub layer of preferred habitats, *Betula sp.* and *Pinus sylvestris* are the most counted species, the second being generally absent in adjacent vegetation's shrub layer (Table 13). For the other variables, p-values do not permit to reject the null hypothesis of mean equality (Table 12). Therefore, species richness, mean height and Braun-Blanket recovery are considered as equal between preferred habitats and adjacent vegetation.

Table 13 - Mean number of individuals found per species, according to the type of zone (preferred habitats or adjacent vegetation).

Species	**Preferred habitats**	**Adjacent vegetation**
tree layer		
Picea abies	0.18 ± *0.40*	1.33 ± *2.44*
Pinus sylvestris	1.36 ± *2.62*	2.30 ± *2.60*
Betula sp.	1.00 ± *2.19*	1.70 ± *3.26*
Shrub layer		
picea abies	0.18 ± *0.60*	1.17 ± *1.70*
Pinus sylvestris	6.64 ± *8.09*	0.63 ± *1.25*
Betula sp.	7.64 ± *9.10*	5.97 ± *6.33*
Salix sp.	0.55 ± *1.51*	0.83 ± *3.05*
Sorbus sp.	1.36 ± *4.52*	0.20 ± *0.92*
Populus sp.	0.00 ± *0.00*	0.47 ± *2.56*

Shannon's index reached the values of 0.83 (adjacent zones) and 0.61 (preferred habitats) point out a low level of biodiversity for both zones. Anova did not result in a significant difference (p-value=0.137). There is also no significant difference in Simpson's index (p-value=0.157). In both surveys, the index is lower than 0.5 (0.48 for adjacent vegetation, 0.37 for preferred habitats), meaning than there is more than 50% of chance to have the same species while picking up two random individuals.

8 Discussion

On one hand, this study has shown the importance of taking into account meteorological variables during moose's populations assessment in order to better understand their influences on a density estimation method, the track count and Kilometric Abundance Index. Several studies have already shown winter movements patterns of moose. So, moose would have five periods of activity per 24h, with longer inactivity period (Gillingham, 1992). Moose's movements are easily blended thanks to radio-collared GPS and are widely used trough recent scientific literature (Herfindal, 2009; Olsson, 2011; Melin, 2013). However, knowledge about animal movements can be proving to be effective while assessing population density. Keeping (2014b) has already shown a dependence of KAI on mean daily distance made by the studied species. Therefore, this study focuses on external parameters that indirectly influence KAI, by impacting moose's movements. Results point out the influence of three meteorological parameters: snow depth, snow sinking and maximal daily temperature. This way, better adjustments would be made when assessing populations, regarding to meteorological conditions.

On the second hand, mapping moose's winter distribution is also a great tool to manipulate, in order to better visualize their needs. Furthermore, results about winter habitat selection could be interesting tools when managing Finnish forests, by integrating moose's requirements in forest operations. Studies usually used radio-collared GPS to localise moose and assess their habitat's needs (Dettki, 2003; Poole, 2006.). However, this method is not without constraint. First, high costs associated with radio-collared GPS are often a problem for research's budget. Secondly, installation of neckless needs an immobilization and human intervention on the selected animal, which can impact its behaviour. It is so necessary to use no disturbing methods to better accurate winter habitat selection. Månsson (2011a) has shown that using pellet group counting method as a tool to localise preferred habitats can lead to similar results. However, resting places seem to be more significant when studying habitat selection, due to the selection of resting areas, instead of random droppings. It is why this study put more weight on resting places, while keeping droppings in the data. Furthermore, it is essential to compare adjacent vegetation from preferred habitats while determining selection, in order to better observe a clear choice. This comparison would help the comprehension of moose's behaviour while foraging.

Kilometric Abundance Index

The model built to predict KAI by meteorological variables allows a relatively well estimation. Three variables were retained. Two come from direct measurement (snow depth and snow sinking) while one is data recovery from the nearest weather station. During this experimentation, KAI was particularly erratic, leading to difficulties in building a model. However, it is normal to have such results, due to hazardous movements of moose. In its study, Becker (2015) found also an irregular evolution of KAI, saying that the number of tracks found can be influenced by several factors. Therefore, the model built in this study looks more like an indicator of change than a real predictor.

In this study, KAI is mostly influenced by snow sinking and daily maximum temperature. As Keeping claims (2014a), KAI is dependent on daily animal's travel. Thus, these two meteorological variables could be a factor striking moose's movements, leading to a such variation of KAI. Moose adapt their metabolism regarding to external conditions. Dussault (2004) found that moose reduce their displacements when winter temperatures exceed -5°c. It corroborates with our measured KAI, where it considerably falls down when the daily maximal temperature reaches positive value. Furthermore, an increasing snow sinking will lead to a reduction of the difficulties to walk in the snow. As Lundmark said (2008), sinking depth of moose while walking is 21cm. Thus, moose can reduce their displacement regarding to a decreasing of snow sinking, leading to a reduction of KAI. A higher snow sinking will also increase the sightability of tracks, as moose will fall deeper in the snow. In contrast, moose will walk more with a good snow quality, leading to an increasing KAI. Snow hardness and humidity also influenced KAI, but these factors seem to be intimately linked with atmospheric temperature. An increasing temperature will lead to a hardening of shallow snow and an increasing snow humidity.

During this study, three transects, of 10-15km, has been dimensioned to measure daily KAI, each of them randomly localised across the study area. Results show a different KAI measured from each transect. This difference proves that the localisation of transect takes a big importance while assessing moose's populations. In areas with low density population, the fact that moose tend to avoid all humans contacts is significant (Glushkov, 2013). Transect three was close to residential areas and routes, it potentially explaining a lower KAI than transect two. The transect two was localised in areas without any snow-cleared routes and habitations, resulting in a quiet space suitable for moose's winter distribution. Furthermore, moose adapt their behaviour due to external factors, such as predator's presence or nutriments foraging, and can migrates for several kilometres (Andersen, 1991). Therefore, some transect's realisations may lead to a lack of data if some predators, wolves and bears, end up around this transect. However, Herfindal (2009) found that home range of moose is more related to the foraging conditions than human's disturbance. In any case, to avoid mis-estimation, residential areas should be taken into account during the procedure.

KAI gathering of this study was regularly collected, providing continuous data easily analysable. Therefore, the evolution of KAI is more accurate and reliable to the reality. In other studies on population estimation do generally not use continuous data. They usually focus on a one-time measured KAI to give global conclusions This way, they increase the risk of under-estimation if no animals crossed the transect the days before the assessment (Becker, 2015). Furthermore, it is important to do the estimation several times a year, as moose's footprint in snow usually loses his freshness after only three hours (Lundmark, 2008). However, Finnish Game and Fisheries Research Institute gives every year a KAI per day, without doing triangle consensus more than one time a season (Pellikka, 2005). It points out the reliability of a vulnerable system coping with sampling errors and rough extrapolation.

Winter habitat selection

Results of crossing between heatmap and Corine Land Cover point out a clear preference for regeneration vegetation, without trees cover, giving a considerable amount of nutrients values. Even if forests are represented trough the results, these growth on peatland, resulting in a small height and weaker growth rate. Similar results were found in Sweden and support a biggest representation of pellets group in vegetation with a cover of Scot pine ≤20% (Månsson, 2012). Quadra analysis also showed a tree cover less dense in preferred habitats, and a clear tree's dominance in adjacent vegetation. General consensus converges to the same conclusion: in winter, moose is mostly a cut-overs species (Mcnicol, 1980; Courtois, 2002; Dussault, 2006). besides furnishing a lot of high nutrients species, cut-overs offer to moose open spaces and therefore, the opportunity to keep an eye on potential predators as well as an easiest vegetation to cross during escapes.

Data collected for moose's habitat determination also gave information about winter diet. Results showing an avoidance of tree dominant land cover, preferred habitats are mostly represented by a dense shrub layer, cover exceeding 75%. Winter diet can therefore be constituted of shrub species, such as birch and young pine, abundant in the vegetation. Wam (2010) found similar results, showing that less than five species constitute the winter diet with a strong selection for birch among the species. In contrast, Månsson (2007) demonstrated a higher probability of browsing rowan and aspen than birch and Scot pine. However, the present study does not aim to provide a precise determination of winter diet. Its first goal was a study of winter habitat, diet only comes indirectly from this habitat. Therefore, knowing habitat characteristics do not permit precise conclusions of diet but can give some information about the vegetation type included in it.

Production of heatmaps is a useful tool for all managers wishing to preserve the well-being of the animals living in its forest. This study used local found items to build it, droppings and resting places. It gives reasonable indications of local-scale distribution over the small study area. In the present case, moose are widely distributed over it, with 4 more occupied zones. Although preferred habitats, moose also used other types of vegetation, for migration or foraging. Using heatmaps in forest management can therefore help foresters to adapt operations regarding to moose's distribution, by preserving preferred zones from all types of disturbance, creating quiet spaces for moose. Several other studies have been used mapping and Land Cover data to assess moose's habitat needs (Olsson, 2011; Melin, 2013). However, at thin scale, GIS analysis usually is completed with radio-collared GPS, in order to have a continuous and direct information about moose's movements. At large scale, using GIS analysis provide a long-term tool to survey moose's populations distribution and expansion (Jensen, 2018).

Electivity indices have given similar results about habitat selection, with a clear preference of regeneration clear-cut habitats and an avoidance of anthropogenic zones and water bodies. Although absolute values are different, Vanderploeg index results more often to preference choice while others give negative value for the same habitat, but ranking is still arranged the same way. Therefore, it conducts to similar conclusion about differences of selection among several types of habitats. Same conclusions about ranking similarities have been also shown in previous study (Lechowicz, 1982). Their strong reliabilities make these electivity indices a good tool while studying resources selection. They can either been used in determination of feeding selection (Hjeljord, 1990) than for habitat selection (Garneau, 2008).

Methodology issues and perspectives

KAI

In order to improve the accuracy of measuring daily KAI, it could be necessary to realise transects more often. In fact, transects were done weekly, and transformed into a daily index. This assumption of equivalent KAI during several following days leads to consistent errors. Moose walking a daily average 1km, their movements are variable and depend on current conditions. Therefore, there is an uncertainty about constant movements over the time, which can lead to mis-estimation of daily KAI

(Stephens, 2006). New tracks seen during transect realisation were considered as fresh, but there were freshness differences within the sampling, some tracks fresh from 24h while others were made four days before. Instead of doing this extrapolation, more regular transect realisation should be made to better accurate the reality. In addition, stronger focus on meteorological conditions should be done to observe KAI change before or after meteorological changes (snowing, increasing temperatures, etc.).

Data were collected on a total transect distance of 41.7km. In its evaluation of FMP formula, Stephen's study (2006) was based on longer distances, variating between 100km and 1,800km. On contrary, keeping (2014a) used a total transect distance of 30km, to give similar results. The results of this study, coupled with the conclusions of the others, bring up the question of minimal distance to achieve in order to collect significant and robust data set. It could be interesting to conduct further study on mileage effort to be produced before having accuracy stasis. Therefore, focus should be made on the accumulation of moose's footprint seen per each new kilometre done. from a certain distance travelled, KAI must settle down on a value. By doing this kind of research, forest and wildlife manager will have an order of magnitude of distance to achieve for a correct moose's populations assessment, while minimizing human effort. Therefore, by coupling the results of the present study and further researches, estimations will be more and more accurate.

Winter habitat selection

On winter habitat determination, this study has clearly shown its scientific limits. However, these limits appear to be achievable, by amending methods used, or even the study area itself. Therefore, for each limit, a solution to overcome it will be suggested.

First, the small study area does not permit a general conclusion. The 981km² study area appears to be too small in order to determine habitat selection of a such big mammalian as moose, which is worldwide represented and is not endemic from Finland (IUCN, 2015). In fact, the low moose density in the study area means that few animals were indirectly studied, about seven moose within the total area. Therefore, it is difficult to conclude about a winter habitat selection only on the basis of seven surveyed moose. In addition, differences in available habitats, climate and human's disturbance, as well as the local home range between each part of its distribution range could affect moose's behaviour (Herfindal, 2009). In order to encompass a more significant moose sample and a larger panel of available habitats, an enlargement of the study could be a solution. However, this enlargement must take into account humans means, and road network, as not every road is cleared from snow during tuff winter. This expansion could increase the number of indirect surveyed moose, making the sample more robust.

Second, samples used for habitat determination were insufficient to get a normal population. Sample size was 41, unequally distributed over the two types of studied vegetations, leading to an impossibility of absolute comparison. Therefore, sampling does not unable correct analysis, due to statistical bias, and conclusions drawn do not aim to get a general consensus. Principal variables that gave bias to samples were tree cover and tree number, especially in preferred habitats. In samples used for, five quadrats were characterized by an absence of trees, meaning a tree recovery of zero. As the six remaining quadrats have positive values for these following characteristics, statistical parameters are so biased, and heterogenic. Therefore, there is a need in conducting more vegetation survey, in order to highlight a tendency in these two characteristics. With more quadrats, sample size will be bigger enough to get a more reliable sampling the reality, this by including more values for statistical parameters calculation.

Thirdly, this study had got his data on one gathering season, whereas moose is a semi-migratory species. When studying winter habitat selection, data usually are collected over several years periods (Courtois, 2002; Dettki, 2003). The aim of this study proposes an original approach in moose’s habitat determination and should therefore continue its survey effort through the next years, in order to highlight a tendency in winter habitat selection.

9 Conclusion

Study of impact of meteorological conditions on KAI has shown that this can be correctly predicted by using three variables (snow depth, snow sinking and daily maximal temperature). Moose adapting its behaviour according to snow conditions, these results are therefore suitable, as KAI depends directly on moose's movements. With such results, it could be easier to predict KAI before doing the assessment. This way, the choice of the assessment day could be chosen thanks to meteorological parameters. However, despite the assumption of this model to predict KAI, it should not be forgotten that KAI is still a dependent variable. Moose can walk on a long distance even with poor conditions. Moreover, choice of transect localisation can also leads to differences in assessment.

Part two of this study has tried to characterized vegetation of preferred habitats. If data has led to similar results found in literature, originality of this study is based on comparison with adjacent vegetation, in order to highlight differences or similarities. It enables to understand better the influences of vegetation on moose choice while selecting a habitat more than another. However, this study was based on one-year data, giving limited information about a clear habitat selection. Therefore, additional effort is needed to continue data gathering. Collecting data over several years will help to highlight a tendency in winter habitat selection.

It is so with encouraging results that this study leads to improvement solutions.

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Appendices

Appendix 1 : daily collected data for evaluation of meteorological influence on KAI. (SHA=snow hardness SHU=snow humidity SD=Snow depth SS=snow sinking MIT=minimal temperature MAT=maximal temperature TG=temperature gap T=mean temperature P=precipitation W=maximum wind speed H=atmospheric humidity KAI=Kilometric Abundance Index).

Date	**SHA**	**SHU**	**SD**	**SS**	**MIT**	**MAT**	**TG**	**T**	**P**	**W**	**H**	**KAI**
22.01.2019	1	1	42	21	-28.6	-15.6	13	-22.1	3	2	84	1.470
23.01.2019	1	1	51	21	-24	-12.1	11.9	-18.05	0.5	2	84	1.470
24.01.2019	1	1	51	21	-31.8	-22.7	9.1	-27.25	0	0	81	1.470
25.01.2019	1	1	51	21	-27.7	-17.8	9.9	-22.75	1.10	0	82	1.470
26.01.2019	1	1	52	21	-22.2	-15.4	6.8	-18.8	0.8	4	84	1.470
27.01.2019	1	1	50	21	-28.9	-15.8	13.1	-22.35	0.2	3	82	1.470
28.01.2019	1	1	52	19	-34.4	-20	14.4	-27.2	0	3	77	1.470
29.01.2019	1	1	53	20	-20	-10.8	9.2	-15.4	2.9	2	85	1.470
30.01.2019	1	1	55	20	-11.3	-3.1	8.2	-7.2	2.3	3	92	1.110
31.01.2019	1	1	55	20	-23.5	-5.5	18	-14.5	0	3	84	2.525
01.02.2019	1	1	55	19	-26	-17.2	8.8	-21.6	0	2	81	2.525
02.02.2019	1	1	56	19	-27.8	-13.6	14.2	-20.7	0	3	82	2.525
03.02.2019	1	1	56	19	-24.2	-12.9	11.3	-18.55	4.3	5	83	2.525
04.02.2019	1	1	60	25	-12.8	-7.9	4.9	-10.35	0.4	5	89	2.525
05.02.2019	1	1	54	21	-16	-7.4	8.6	-11.7	4.4	3	85	2.525
06.02.2019	1	1	58	19	-20.6	-9	11.6	-14.8	0.1	3	84	2.131
07.02.2019	1	1	60	20	-21.2	-5.1	16.1	-13.15	1.6	3	87	2.131
08.02.2019	1	1	60	30	-5.1	0.3	5.4	-2.4	0.7	5	95	1.816
09.02.2019	1	1	59	20	-0.6	0.9	1.5	0.15	1.9	6	90	1.816
10.02.2019	1	2	59	18	0.4	1.9	1.5	1.15	1.3	8	94	1.816
11.02.2019	1	2	58.5	15	0	1.9	1.9	0.95	5.4	7	95	1.437
12.02.2019	1	1	60	13	-10.1	0.1	10.2	-5	0	5	91	1.760
13.02.2019	1	1	59	10	-12	-7.1	4.9	-9.55	2.8	3	94	1.760
14.02.2019	1	2	60	6	-7.7	-1.1	6.6	-4.4	2.8	6	93	1.760
15.02.2019	1	2	59	6	-1.1	4.7	5.8	1.8	0	8	70	0.907
16.02.2019	1	2	59	6	-7.5	2.5	10	-2.5	0.1	7	85	0.907
17.02.2019	1	2	57	7	-4.2	2.3	6.5	-0.95	0.1	12	65	0.907
18.02.2019	1	2	55	9	-18.8	-3.2	15.6	-11	0.9	7	94	0.907
19.02.2019	1	2	61	10	-3.8	2	5.8	-0.9	1.6	5	96	0.907
20.02.2019	1	2	57	14	-6.8	1.4	8.2	-2.7	3.2	10	92	0.833
21.02.2019	1	1	62	9	-16.2	-7.6	8.6	-11.9	0	9	92	0.833
22.02.2019	1	1	64	10	-24.7	-7.7	17	-16.2	3.5	5	91	1.010
23.02.2019	1	1	62	10	-8.2	5.1	13.3	-1.55	0	4	100	1.010
24.02.2019	1	2	60	9	-9.1	3.3	12.4	-2.9	0.5	5	100	1.010
25.02.2019	1	2	59	9	0.7	4.9	4.2	2.8	0.2	7	93	1.010
26.02.2019	1	1	62	10	-8.1	2	10.1	-3.05	0.6	5	96	0.860
27.02.2019	1	3	61	9	-10.6	3.9	14.5	-3.35	4.4	5	89	0.860
28.02.2019	1	1	64	7	-9.7	1.2	10.9	-4.25	0	9	100	0.860

Date	SHA	SHU	SD	SS	MIY	MAT	TG	T	P	W	H	KAI
01.03.2019	3	1	62	8	-20.7	-4.8	15.9	-12.75	1.1	5	92	1.183
02.03.2019	1	1	62	7	-8.1	-3.3	4.8	-5.7	11.2	7	93	1.183
03.03.2019	1	1	65	10	-18.6	-4.5	14.1	-11.55	0	7	94	1.183
04.03.2019	1	1	68	15	-17.9	-7.1	10.8	-12.5	0	3	87	1.183
05.03.2019	1	1	71	15	-13	-7.1	5.9	-10.05	0	6	78	0.603
06.03.2019	1	1	72	17	-27.9	-5.6	22.3	-16.75	0	6	65	0.603
07.03.2019	1	1	72	17	-8	-2.9	5.1	-5.45	1.3	4	88	0.603
08.03.2019	1	1	74	17	-3.2	2.3	5.5	-0.45	8	5	93	0.533
09.03.2019	1	2	76	10	-6.6	2.4	9	-2.1	1.5	7	88	0.533
10.03.2019	1	1	79	11	-14.5	-0.7	13.8	-7.6	6.5	3	94	0.533
11.03.2019	1	1	76	13	-13.5	-3	10.5	-8.25	0.5	3	97	0.533
12.03.2019	1	1	78	11	-17	-2.2	14.8	-9.6	0.2	8	78	0.513
13.03.2019	1	1	76	11	-22.5	-1.5	21	-12	0	3	95	0.513
14.03.2019	1	1	74	12	-11.3	0.8	12.1	-5.25	0.1	6	77	0.513
15.03.2019	1	1	74	12	-1.2	1.6	2.8	0.2	2.2	5	93	0.423
16.03.2019	1	3	75	11	0.3	2	1.7	1.15	0.5	4	89	0.423
17.03.2019	1	3	76	11	-0.8	1.7	2.5	0.45	2	4	90	0.423
18.03.2019	1	3	85	11	0.5	1.8	1.3	1.15	1	4	95	0.423
19.03.2019	1	3	75	10	0.5	3.2	2.7	1.85	0.6	4	95	0.343
20.03.2019	1	3	74	3	-1	1.9	2.9	0.45	1	5	89	0.343
21.03.2019	1	3	80	6	-1.5	2.3	3.8	0.4	1	4	87	0.343
22.03.2019	1	3	77.5	6	-2.1	4.2	6.3	1.05	0	10	81	0.343
23.03.2019	1	3	75	5	-8	2.3	10.3	-2.85	0.3	10	71	0.343
24.03.2019	1	3	74	5	0	4.3	4.3	2.15	0	7	70	0.343
25.03.2019	1	3	73	5	-1.8	2.2	4	0.2	4.4	5	87.7	0.343
26.03.2019	2	2	83	10	-6.1	0.3	6.4	-2.9	0	7	82	0.530
27.03.2019	3	2	78	9	-13.2	1.4	14.6	-5.9	0	4	74	0.530
28.03.2019	3	2	79	6	-7.8	4.3	12.1	-1.75	0	6	83.5	0.530
29.03.2019	3	2	75	5	2.3	9.2	6.9	5.75	0	9	57	0.993
30.03.2019	2	2	72	5	-4.5	6.3	10.8	0.9	0	9	58.5	0.993
31.03.2019	2	1	68	4	-5.3	4.5	9.8	-0.4	0	6	65	0.993
01.04.2019	2	1	67	4	-2.9	3.1	6	0.1	0	6	66	0.993
02.04.2019	2	3	70	2	-1.8	7.5	9.3	2.85	0	5	60	0.239
03.04.2019	3	3	60	5	-2.5	7.8	10.3	2.65	0	6	49	0.239
04.04.2019	2	3	58	8	0.5	9.4	8.9	4.95	0	7	49.5	0.239
05.04.2019	2	3	56	14	0.4	6.2	5.8	3.3	0	5	87	0.239
06.04.2019	2	3	54	7	-1.5	10.7	12.2	4.6	0	3	76.5	0.239
07.04.2019	2	3	52	5	-6.6	11.7	18.3	2.55	0	2	68	0.239
08.04.2019	3	3	51	4	-4.8	7.3	12.1	1.25	3.6	6	73	0.239
09.04.2019	1	3	63	13	-3.6	0.4	4	-1.6	10.7	8	93	0.208
10.04.2019	1	2	67	14	-4.6	-2.1	2.5	-3.35	2.6	9	90	0.208
11.04.2019	1	2	60	16	-5.2	1.6	6.8	-1.8	0	7	64	0.208
12.04.2019	2	2	56	13	-12.6	4.9	17.5	-3.85	0	5	63.5	0.208
13.04.2019	3	3	55	10	-1.7	5.6	7.3	1.95	0	3	71.5	0.208
14.04.2019	3	3	52	7	-0.9	6.8	7.7	2.95	0	4	66	0.208

Date	SHA	SHU	SD	SS	MIY	MAT	TG	T	P	W	H	KAI
15.04.2019	4	3	40	5	-5.6	10.5	16.1	2.45	0	6	59.5	0.208
16.04.2019	4	3	39	2	-6	10.7	16.7	2.35	0	3	66	0.208
17.04.2019	3	3	39	2	-4.3	10.9	15.2	3.3	0	5	60.5	0.264
18.04.2019	3	3	39	2	-4.5	11.5	16	3.5	0	3	55	0.264
19.04.2019	3	3	31	2	-2.9	10.5	13.4	3.8	0	7	50	0.398
20.04.2019	3	3	18	3	-5.2	9.5	14.7	2.15	0	3	52	0.398
21.04.2019	3	3	10	3	-4.6	9.6	14.2	2.5	0.4	6	56	0.398
22.04.2019	3	3	7	4	4	11	7	7.5	0	4	61	0.398
23.04.2019	3	3	5	5	0.1	17.2	17.1	8.65	0	5	55	0.398

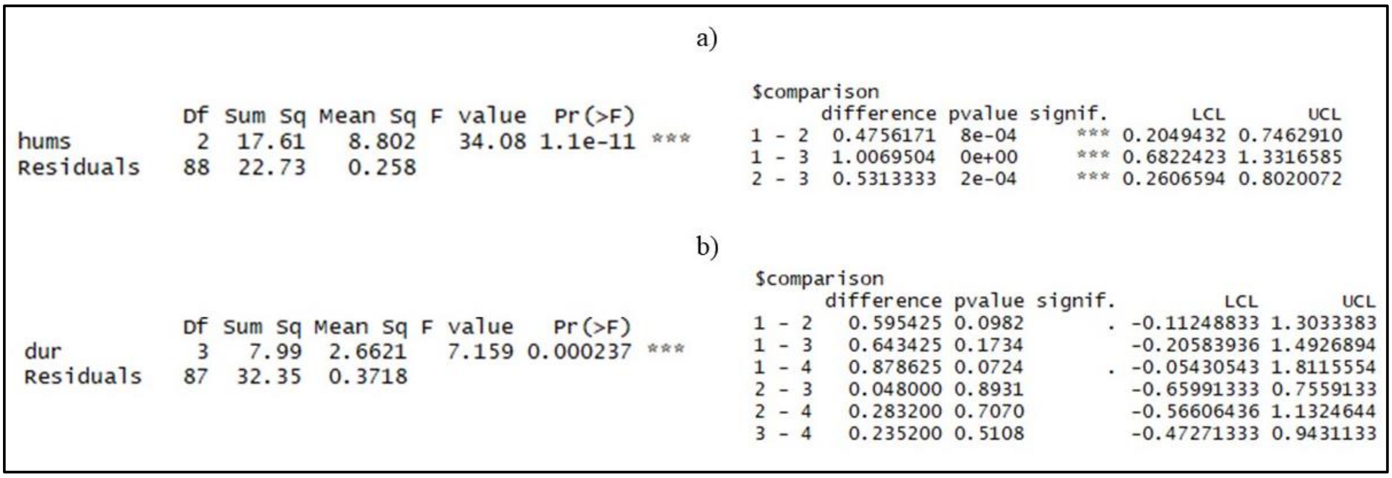
Appendix 2 : Transect’s realisation with number of fresh tracks seen, ordered by date.

Date	Transect n°	Total km	N° of tracks seen
22-01-2019	1	15.5	0
29-01-2019	1	15.5	16
31-01-2019	2	13.4	0
05-02-2019	1	15.5	12
07-02-2019	2	13.4	37
11-02-2019	1	15.5	3
11-02-2019	3	12.8	0
14-02-2019	2	13.4	31
19-02-2019	3	12.8	7
20-02-2019	1	15.5	18
21-02-2019	2	13.4	7
25-02-2019	3	12.8	6
28-02-2019	1	15.5	12
28-02-2019	2	13.4	12
04-03-2019	1	15.5	14
04-03-2019	3	12.8	3
07-03-2019	2	13.4	9
11-03-2019	1	15.5	8
11-03-2019	3	12.8	1
14-03-2019	2	13.4	7
18-03-2019	1	15.5	5
18-03-2019	3	12.8	3
25-03-2019	1	15.5	6
25-03-2019	3	12.8	0
28-03-2019	2	13.4	9
01-04-2019	1	15.5	12
01-04-2019	2	13.4	10
01-04-2019	3	12.8	0
08-04-2019	1	15.5	2
08-04-2019	2	13.4	5
08-04-2019	3	12.8	0
16-04-2019	3	12.8	1
18-04-2019	1	15.5	2
23-04-2019	2	13.4	8

Appendix 3 : Vegetation survey in order to study winter habitat selection. (PH=preferred habitat AV=adjacent vegetation h=mean height (m) sp=species richness nb=number of individuals r=Braun-Blanket recovery).

num	type	h_tree	h_shrub	sp_tree	sp_shrub	nb_tree	nb_shrub	r_tree	r_shrub
1.1	PH	0	1.68	0	2	0	45	0	4
1.2	AV	7.2	2.56	2	2	8	2	5	3
1.3	AV	8.25	2.05	2	3	8	14	6	5
1.4	AV	5.86	1.4	2	5	12	20	5	5
1.5	AV	14.33	0	2	0	8	0	6	0
2.1	PH	17	0.84	1	2	1	16	3	4
2.2	PH	0	1.59	0	3	0	19	0	4
2.3	AV	5.48	1.17	2	3	5	10	4	3
2.5	AV	14.83	0	2	0	3	0	3	0
2.6	AV	14.44	0.55	3	2	5	4	5	1
3.1	PH	0	2.24	0	1	0	12	0	3
3.2	AV	18.33	1.15	1	1	3	2	5	3
3.3	AV	16.5	2.66	1	1	2	12	4	4
3.4	AV	12	2.7	2	1	3	10	4	3
4.1	PH	13	2.08	1	2	8	17	5	3
4.2	PH	9.29	1.2	3	1	7	1	5	1
4.3	AV	7.92	1.36	2	2	8	6	5	3
4.4	AV	8	1.45	1	2	5	12	4	4
4.5	AV	9.2	1.19	1	1	5	14	4	3
4.6	AV	6.18	2.15	1	1	5	2	4	2
5.1	PH	0	1.37	0	1	0	13	0	4
5.2	PH	0	1.72	0	1	0	15	0	4
5.3	AV	13	1.24	1	1	1	10	3	4
5.4	AV	15	1.96	1	1	1	8	3	3
5.5	AV	12.6	1.11	1	2	5	7	5	3
5.6	AV	12	2.2	1	1	5	1	3	5
6.1	PH	5.3	2.04	1	2	7	9	4	5
6.2	AV	6.83	1.82	2	3	9	34	5	5
6.3	AV	9.25	0.48	2	2	7	4	6	1
6.4	AV	6.5	1.8	2	2	7	20	5	4
6.5	AV	7.5	2.06	1	1	3	8	3	3
7.1	PH	14.2	0	2	0	5	0	5	0
7.2	AV	14.66	0	1	0	3	0	4	0
7.3	AV	0	2.47	0	3	0	19	0	5
7.4	AV	0	0.67	0	2	0	9	0	4
7.5	AV	21.66	0.5	2	1	3	1	5	2
8.1	PH	0	1.85	0	3	0	33	0	6
8.2	AV	12	1.37	1	2	3	9	6	2
8.3	AV	15.2	0	1	0	6	0	6	1
8.4	AV	10.2	2.3	1	2	11	15	5	5
8.5	AV	8.5	1.06	1	2	16	25	5	4

Appendix 4 : One-way Anova and Newman & Keuls means structuration between KAI and snow humidity (a) and snow hardness (b).



a)

```
            Df Sum Sq Mean Sq F value  Pr(>F)    
hums         2  17.61   8.802   34.08 1.1e-11 ***
Residuals   88  22.73   0.258                    
```

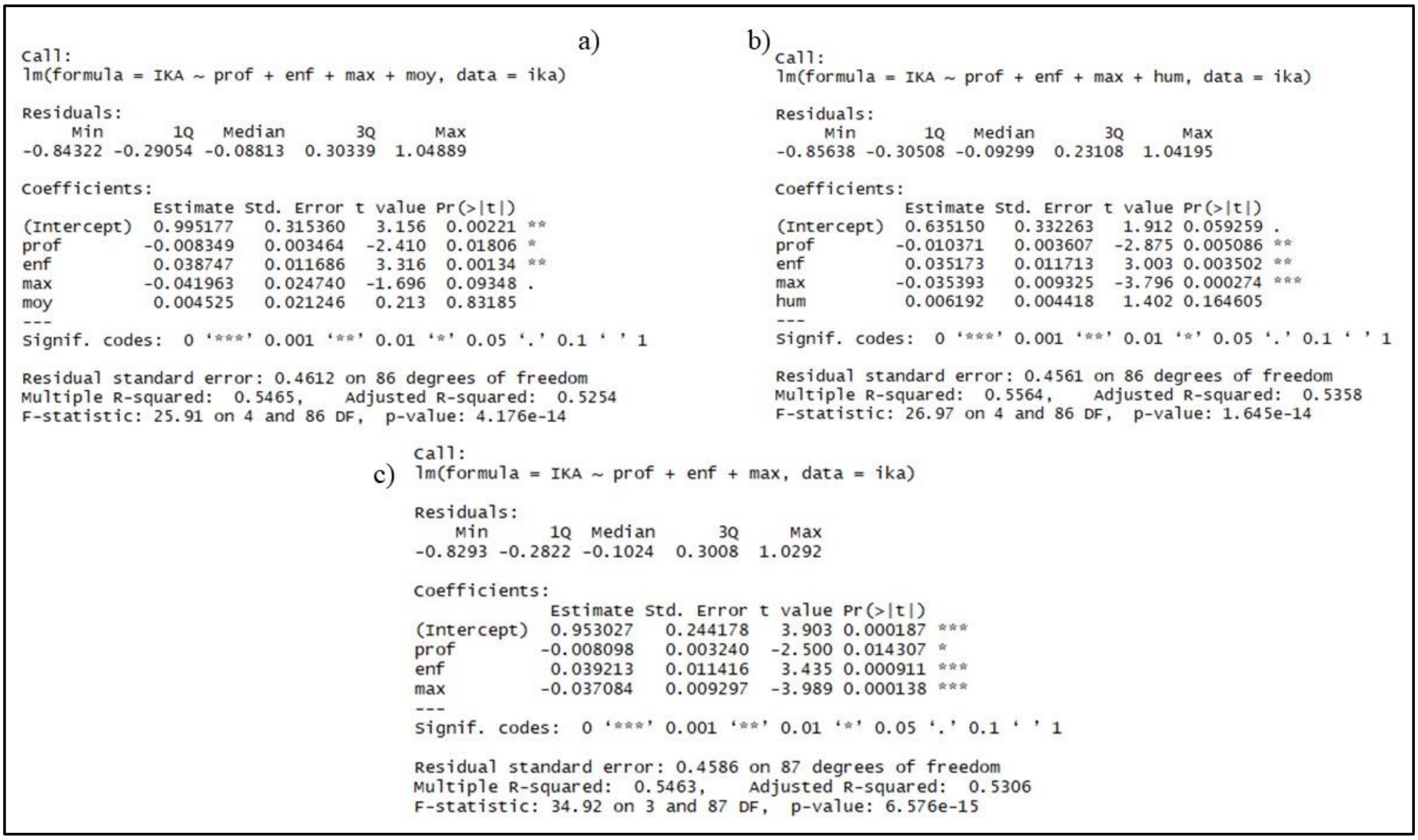
```
$comparison
      difference pvalue signif.       LCL       UCL
1 - 2  0.4756171  8e-04     *** 0.2049432 0.7462910
1 - 3  1.0069504  0e+00     *** 0.6822423 1.3316585
2 - 3  0.5313333  2e-04     *** 0.2606594 0.8020072
```

b)

```
            Df Sum Sq Mean Sq F value   Pr(>F)    
dur          3   7.99  2.6621   7.159 0.000237 ***
Residuals   87  32.35  0.3718                     
```

```
$comparison
      difference pvalue signif.         LCL       UCL
1 - 2   0.595425 0.0982       . -0.11248833 1.3033383
1 - 3   0.643425 0.1734         -0.20583936 1.4926894
1 - 4   0.878625 0.0724       . -0.05430543 1.8115554
2 - 3   0.048000 0.8931         -0.65991333 0.7559133
2 - 4   0.283200 0.7070         -0.56606436 1.1324644
3 - 4   0.235200 0.5108         -0.47271333 0.9431133
```

Appendix 5 : Summary of lm procedure in R software in order to study models predicting daily KAI. A) model with snow depth, snow sinking, maximal temperature and mean temperature. B) model with snow depth, snow sinking, maximal temperature and atmospheric humidity. C) model with snow depth, snow sinking and maximal temperature.



a)

```
Call:
lm(formula = IKA ~ prof + enf + max + moy, data = ika)

Residuals:
     Min       1Q   Median       3Q      Max 
-0.84322 -0.29054 -0.08813  0.30339  1.04889 

Coefficients:
             Estimate Std. Error t value Pr(>|t|)   
(Intercept)  0.995177   0.315360   3.156  0.00221 **
prof        -0.008349   0.003464  -2.410  0.01806 * 
enf          0.038747   0.011686   3.316  0.00134 **
max         -0.041963   0.024740  -1.696  0.09348 . 
moy          0.004525   0.021246   0.213  0.83185   
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.4612 on 86 degrees of freedom
Multiple R-squared:  0.5465,	Adjusted R-squared:  0.5254 
F-statistic: 25.91 on 4 and 86 DF,  p-value: 4.176e-14
```

b)

```
Call:
lm(formula = IKA ~ prof + enf + max + hum, data = ika)

Residuals:
     Min       1Q   Median       3Q      Max 
-0.85638 -0.30508 -0.09299  0.23108  1.04195 

Coefficients:
             Estimate Std. Error t value Pr(>|t|)    
(Intercept)  0.635150   0.332263   1.912 0.059259 .  
prof        -0.010371   0.003607  -2.875 0.005086 ** 
enf          0.035173   0.011713   3.003 0.003502 ** 
max         -0.035393   0.009325  -3.796 0.000274 ***
hum          0.006192   0.004418   1.402 0.164605    
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.4561 on 86 degrees of freedom
Multiple R-squared:  0.5564,	Adjusted R-squared:  0.5358 
F-statistic: 26.97 on 4 and 86 DF,  p-value: 1.645e-14
```

c)

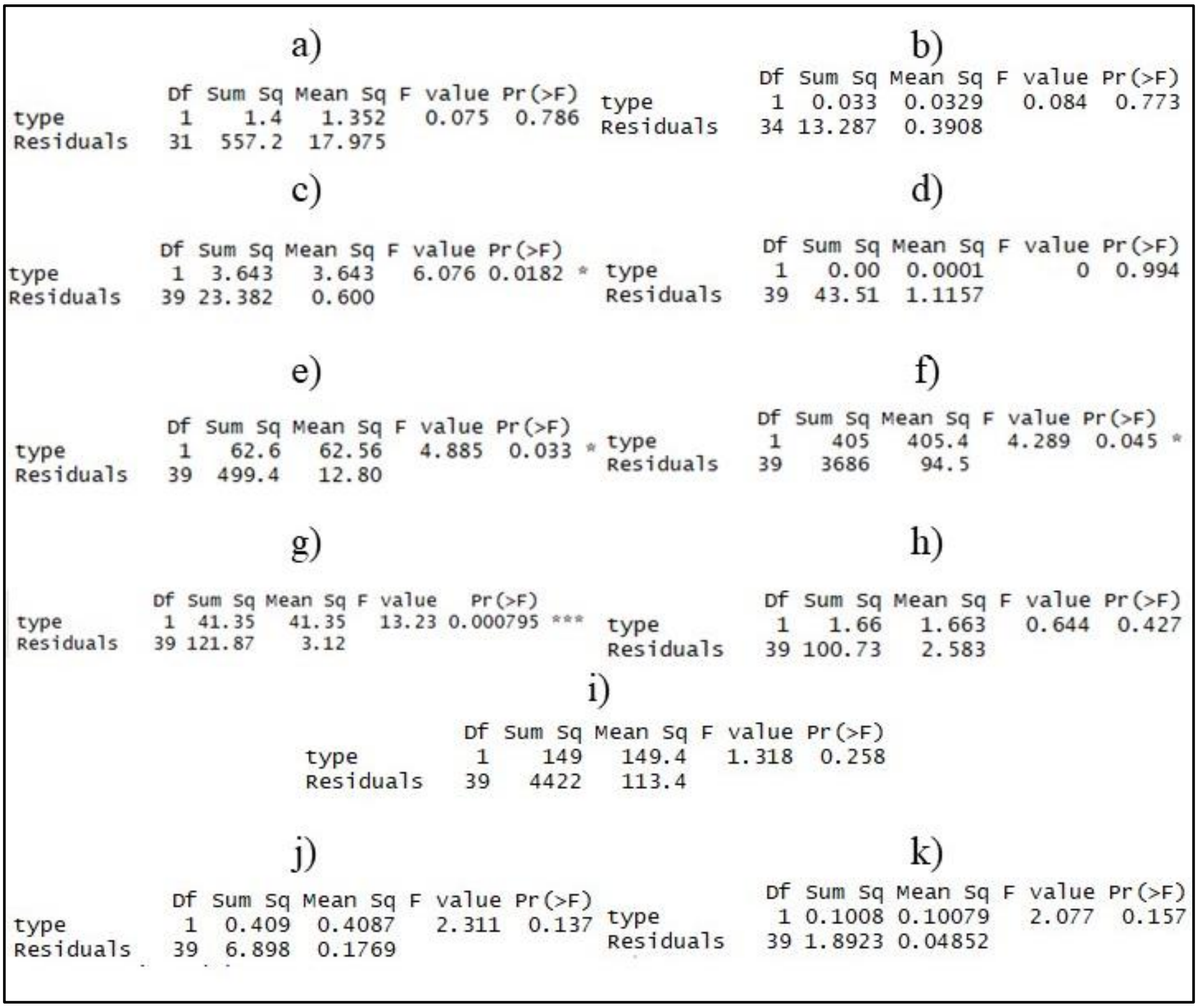
```
Call:
lm(formula = IKA ~ prof + enf + max, data = ika)

Residuals:
    Min      1Q  Median      3Q     Max 
-0.8293 -0.2822 -0.1024  0.3008  1.0292 

Coefficients:
             Estimate Std. Error t value Pr(>|t|)    
(Intercept)  0.953027   0.244178   3.903 0.000187 ***
prof        -0.008098   0.003240  -2.500 0.014307 *  
enf          0.039213   0.011416   3.435 0.000911 ***
max         -0.037084   0.009297  -3.989 0.000138 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.4586 on 87 degrees of freedom
Multiple R-squared:  0.5463,	Adjusted R-squared:  0.5306 
F-statistic: 34.92 on 3 and 87 DF,  p-value: 6.576e-15
```

Appendix 6 : One-way Anova results in compare variables between preferred habitats and adjacent vegetation. A) height (tree). B) height (shrub). C) species richness (tree). D) species richness (shrub). E) number of individuals (tree). F) number of individuals (shrub). G) Braun-Blanket recovery (tree). H) Braun-Blanket recovery (shrub). I) total number if individuals (all type of layer). J) Shannon index. K) Simpson index



a)

```
            Df Sum Sq Mean Sq F value Pr(>F)
type         1    1.4   1.352   0.075  0.786
Residuals   31  557.2  17.975
```

b)

```
            Df Sum Sq Mean Sq F value Pr(>F)
type         1  0.033  0.0329   0.084  0.773
Residuals   34 13.287  0.3908
```

c)

```
            Df Sum Sq Mean Sq F value Pr(>F)
type         1  3.643   3.643   6.076 0.0182 *
Residuals   39 23.382   0.600
```

d)

```
            Df Sum Sq Mean Sq F value Pr(>F)
type         1   0.00  0.0001       0  0.994
Residuals   39  43.51  1.1157
```

e)

```
            Df Sum Sq Mean Sq F value Pr(>F)
type         1   62.6   62.56   4.885  0.033 *
Residuals   39  499.4   12.80
```

f)

```
            Df Sum Sq Mean Sq F value Pr(>F)
type         1    405   405.4   4.289  0.045 *
Residuals   39   3686    94.5
```

g)

```
            Df Sum Sq Mean Sq F value   Pr(>F)
type         1  41.35   41.35   13.23 0.000795 ***
Residuals   39 121.87    3.12
```

h)

```
            Df Sum Sq Mean Sq F value Pr(>F)
type         1   1.66   1.663   0.644  0.427
Residuals   39 100.73   2.583
```

i)

```
            Df Sum Sq Mean Sq F value Pr(>F)
type         1    149   149.4   1.318  0.258
Residuals   39   4422   113.4
```

j)

```
            Df Sum Sq Mean Sq F value Pr(>F)
type         1  0.409  0.4087   2.311  0.137
Residuals   39  6.898  0.1769
```

k)

```
            Df Sum Sq Mean Sq F value Pr(>F)
type         1 0.1008 0.10079   2.077  0.157
Residuals   39 1.8923 0.04852
```

Appendix 7 : Boxplot for each variable of the vegetation survey. Results are dived into the two type of zones: adjacent vegetation (AV) and preferred habitats (PH). Means are represented by a black point