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Carnivore proof fences : a fragmentation factor for wild ungulate

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VetAgro Sup

Thesis for the end of engineering studies

Carnivore proof fences :

**A fragmentation factor for wild
ungulates**

Pierre LISSILLOUR

Agriculture Environment Health Territories

2021-2022

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Résumé en français

Introduction

Bien que la Norvège ait peu de surface arable (3 % de la surface terrestre), elle possède beaucoup de terres non cultivées comme les montagnes et les forêts. Ainsi, de nombreux agriculteurs utilisent les terres arables pour la production de fourrage d'hiver et pratiquent le pâturage en plein air dans les forêts et les montagnes pendant l'été (Strand et al. 2019). La vulnérabilité du bétail à la prédation lorsqu'il pâture sans surveillance est un grand défi en Norvège, car ce pays abrite quatre grandes espèces de carnivores. L'agriculture étant l'un des secteurs générant le plus de conflits avec ceux-ci, l'ours brun (*Ursus arctos*), le carcajou (*Gulo gulo*), le loup (*Canis lupus*) et le lynx (*Lynx lynx*) étaient quasiment éteints à la fin du XIXe siècle (Asheim et Mysterud 2004).

La conservation de ces espèces a été rendue possible par les lois publiées en 2004 et 2011, connues sous le nom de « Carnivore Settlements ». L'une des mesures de gestion qui en a résulté a été l'établissement de zones de gestion des carnivores (CMZ), définissant des zones de protection pour les carnivores où les populations sont autorisées à se reproduire et où elles sont maintenues à un niveau seuil tel que défini par le législateur. En dehors des CMZ, les quatre espèces de grands carnivores sont réduites par la chasse avec permis et l'abattage préventif. Chaque carnivore a une CMZ attribuée et plusieurs CMZ peuvent se chevaucher. Au total elles représentent 55% de la surface du pays (Strand 2016) Les zones où les bovins et les ovins paissent pendant l'été peuvent donc se trouver dans une ou plusieurs CMZ, 30% des éleveurs ovins se trouvent dans une de ces zones (Strand 2016). Pour y faire face, les éleveurs doivent donc mettre en place des méthodes pour protéger leur bétail.

La région de Hedmark, dans l'Ouest de la Norvège, est celle où les CMZ des quatre espèces se chevauchent (Strand et al. 2019). Dans la municipalité de Grue et Trysil, certains éleveurs de moutons ont décidé de former une association locale de pâturage (LGA). Cela leur a permis de mettre en place un enclos anti-carnivores dans lequel ils peuvent mettre leurs moutons pendant l'été. Cependant, Grue et Trysil gèrent leur clôture différemment. Trysil démonte la clôture pendant l'hiver alors que Grue laisse la clôture en place toute l'année.

La mise en place de ces clôtures permet aux moutons de paître en toute sécurité dans la forêt, et favorise ainsi un système basé sur le pâturage. Cependant, les ongulés sauvages vivant dans ces forêts sont adaptés à un environnement où la forêt, principale ressource alimentaire, est considérée comme des matériaux de broutage. De plus, si l'enclos empêche les carnivores d'entrer dans la zone de pâturage, il pourrait également rendre difficile l'entrée d'autres mammifères tels que les ongulés présents dans ce pays. Bien que le premier comportement de la plupart des ongulés soit de sauter les clôtures (Harrington et Conover 2006), ces dispositifs de protection du bétail peuvent représenter des facteurs de fragmentation de leur habitat (Scott 1992) et donc une ségrégation de leur ressource alimentaire.

C'est pourquoi l'Inland Norway University of Applied Sciences (INN) a voulu évaluer l'effet de ces clôtures sur leur présence par le biais de comptages de leur fèces. Une campagne de comptage a donc été réalisée de mai à juin 2022 pour savoir si les barrières anti-carnivores mises en place pour protéger le bétail en forêt constituent des facteurs de fragmentation de

l'habitat pour les grands herbivores et de plus, si cet impact peut être atténué selon la façon dont la barrière est gérée.

Systeme herbivores sauvages – forêt boreal

Les Leporidae (lièvre) et les Cervidea (cerf, chevreuil et élan) sont dits allo-enzymatiques (dont les enzymes sont produites par d'autres organismes). Ils digèrent par des processus de fermentation activés par des bactéries. Les Phasianidae (grand tetra et tétra lyre) en revanche, ont un système digestif auto-enzymatique (ils produisent leurs propres enzymes digestives) (Cheeke et Dierenfeld 2010).

Une autre distinction possible peut être faite en fonction de la taille des individus et donc de leur métabolisme (Redjadj et al. 2014). Les petits herbivores (Laporidae et Phasianidae) nécessitent moins de nourriture mais une qualité nutritionnelle élevée qu'ils sont capables de sélectionner (Arsenault et Owen-Smith 2002 ; Redjadj et al. 2014). Tandis que les gros herbivores sélectionnent moins leur nourriture, laquelle étant généralement moins riche, mais consommée en plus grande quantité.

Chez les ruminants, d'autres différences physiologiques plus précises peuvent être évoquées et ont poussé R.R. HOFMANN à la fin du 20ème siècle à publier un article conduisant à une classification des ruminants en 3 catégories :

- "Concentrate selectors (CS)" = Ils ne supportent pas de grandes quantités de fibres dans leur alimentation. Ils consomment principalement des plantes à forte teneur en cellules et en lignine.
- "Grazers ou roughage feeders (GR)" = Ils se nourrissent principalement d'herbe, qui est un aliment fibreux et peu lignifié, et sélectionnent très peu leur alimentation.
- "Intermediate feeders (IM)" = Ils sont adaptés à la fois au pâturage et au broutage et modulent leur régime entre les deux en fonction de la disponibilité des plantes.

Ces différences morphologiques et des facteurs tels que l'appétence, la disponibilité des ressources, l'énergie allouée pour y accéder et ce qu'elles donneront plus tard sont importants pour comprendre les mécanismes qui conduisent à la création d'une niche alimentaire.

De plus, l'environnement joue un rôle aussi très important. En effet l'hiver, la couverture neigeuse peut atteindre une épaisseur de 50cm. L'accessibilité à la nourriture devient alors différente selon les espèces pour plusieurs raisons. La première est simplement due à l'hiver et aux basses températures qui impliquent une phase de dormance chez la plupart des plantes (Arsenault et Owen-Smith 2002). Deuxièmement, l'épaisseur de la couverture neigeuse peut modifier l'accessibilité à la nourriture, et en particulier la hauteur à laquelle les animaux se nourriront. La neige peut empêcher l'accès à la végétation inférieure mais peut aussi permettre l'accès à la végétation supérieure (Arsenault et Owen-Smith 2002).

Les conditions hivernales et la composition des forêts boréales durant cette période amènent donc les herbivores sauvages à s'adapter et à modifier leurs niches alimentaires respectives. Cette période est marquée par un chevauchement plus fort de celles-ci, et conduit donc à un système aux interactions plus fortes d'autant plus si la zone est limitée par certaines clôtures et concentre donc les herbivores dans une zone spécifique.

Problématique d'étude

Les clôtures mises en place pour protéger les moutons en forêt contre les carnivores sont-elles un facteur de fragmentation de l'habitat des ongulés sauvages ? De plus, si un tel impact existe, la façon dont la clôture est gérée peut-elle atténuer ce facteur ?

Méthodologie

A Grue, 3 zones ont été créées :

- zone de contrôle Nord
- zone de pâturage
- zone de contrôle Sud

Ces trois zones sont des zones à forte activité de foresterie. Le stade forestier dominant est la "jeune forêt à l'âge de l'éclaircie" avec une majorité d'épicéas. Les espèces dominantes de la végétation au sol sont les mousses et l'altitude varie entre 274 et 506 mètres avec une moyenne de 373 mètres.

A Trysil, 2 zones ont été créées :

- zone de pâturage
- zone de contrôle Sud

Ces deux zones sont des zones à faible activité de foresterie. Le stade forestier dominant est la "forêt ancienne" avec une majorité d'épicéas. L'espèce dominante de la végétation au sol est partagée entre les mousses pour la zone de pâturage et la myrtille pour le Sud. L'altitude varie entre 596 et 890 mètres avec une moyenne de 756 mètres.

Dans cette étude, l'utilisation d'une méthode indirecte a été préférée pour avoir une meilleure description de l'utilisation de l'habitat des ongulés en hiver. C'est pourquoi il a été décidé d'utiliser la méthode de comptage de piles fécales.

La méthode « Feecal Accumulation Rate » (FAR) a été choisie. Elle nécessite de connaître la date à laquelle la zone a été nettoyée des anciennes piles et donc la date à laquelle les nouvelles se sont accumulées (Smart, Ward, et White 2004). Elle fournit également une estimation plus précise de la population et de l'utilisation des terres que la méthode « Feecal Standing Crop », qui peut conduire à des surestimations et qui est également difficile à mettre en place car nécessite la connaissance de la période de persistance des piles dans un environnement donné (Månsson, Andrén, et Sand 2011).

La date de début de la période de FAR a été fixée au 10 octobre 2021. Cette date correspond approximativement à la fin de la chute des feuilles et au début de la première neige, ce qui marque la fin de l'automne. Comme c'est la première fois que ce travail de terrain a lieu dans les zones d'étude, les placettes d'échantillonnage n'avaient pas été nettoyées auparavant. Néanmoins, seules les piles postérieures à la chute des feuilles ont été comptés, c'est-à-dire que tous les excréments estimés avant l'hiver 2021-2022 ont été considérés comme anciens. Cela a permis de simuler un nettoyage préliminaire de la zone.

Nous avons choisi le même plan d'étude que celui utilisé par Zimmermann et al. 2022 et Versluijs 2018. Celui-ci consiste en des carrés avec cinq placettes d'échantillonnage circulaires de 100m² (rayon 5,64 m), disposés comme les cinq d'un dé (Figure 9). Les carrés ont été répartis de manière homogène dans les zones d'étude. Une placette correspond à une zone de recherche et un carré comprend donc 5 placettes.

Pendant le travail de terrain, nous avons utilisé « kobotoolbox », une suite d'outils gratuits et open-source pour la collecte de données sur le terrain.

Ce formulaire nous a permis d'enregistrer le nombre de piles de cerfs, d'élan et de chevreuils, mais aussi la composition de la forêt et la présence d'autres espèces telles que le lièvre, le grand tétras et le tétras-lyre.

La recherche dans une placette s'est organisée de manière à maximiser nos chances de trouver l'entièreté des piles présentes. Une recherche dans le sens des aiguilles d'une montre a d'abord été réalisée, pour ensuite réaliser une recherche dans le sens inverse des aiguilles d'une montre.

Résultats

L'espèce dominante à Grue et Trysil est l'élan, avec 93% du total des piles trouvés à Grue et 92% à Trysil. Même si Trysil représente une zone plus grande, moins de la moitié de ce qui a été trouvé à Grue y a été enregistré (Figure 15).

A Grue, la plupart des piles d'élan ont été trouvées dans de jeunes forêts, avec 31% dans de jeunes forêts avant la première éclaircie et 30% dans de jeunes forêts en phase d'éclaircissement. Cependant, à Trysil, c'est dans des forêts anciennes que nous avons trouvé la plupart des piles, soit 44% du total des piles d'élan.

En raison du très faible nombre de groupes de piles de chevreuils et de cerfs trouvés au cours de cette campagne et des résultats du test de comparaison des moyennes que nous avons obtenus, nous n'avons traité que les données relatives à l'élan.

La densité moyenne des piles d'élan à Grue était significativement plus faible dans la zone de pâturage que dans les zones de contrôle qui ont une densité similaire entre elles. D'autre part, à Trysil, les moyennes de densité de piles d'élan étaient similaires entre la zone de pâturage et de contrôle. Ces résultats indiquent que la présence d'une barrière est corrélée à la densité de pile que l'on peut trouver.

Afin de confirmer cet effet et de le mettre en parallèle d'autres variables pouvant impacter la présence d'élan, des modèles linéaires généralisés ont été réalisés. Au total 7 modèles ont été testés. Le modèle qui décrit le mieux le nombre de piles trouvées dans un carré est celui qui inclut les variables suivantes :

- Zone
- Distance aux routes
- Altitude
- Jeunes forêts avant la première éclaircie (nombre de placettes par carré ayant de jeunes forêts comme classe d'âge dominante, 0-5, catégorie de peuplement forestier).
- Tourbière (nombre de placettes par carré où la tourbière est le type d'habitat dominant, 0-5, catégorie de peuplement forestier)
- Pin (nombre de placettes par carré où le pin est l'essence dominante, 0-5, catégorie d'essence)
- Myrtille (nombre de placettes par carré où la myrtille est la couche dominante du sol, 0-5, catégorie de végétation au sol).

Les résultats de ce modèle indiquent via la variable zone, qu'être dans la zone de pâturage impact significativement la présence de piles avec une p-value de 3.92×10^{-16} et négativement avec

un coefficient de -1.21. De plus, c'est la variable qui a le plus d'impact sur la variable expliquée parmi les 6 autres. Un tel effet n'est pas visible à Trysil où la variable zone n'est pas significative (Figure 20).

En utilisant le modèle 5, trois graphiques de prédiction ont été créés en utilisant les variables zone, jeune forêt avant le premier éclaircissement et tourbière. Le fait de se trouver dans la zone de pâturage réduit par 3 le nombre de piles trouvées à Grue, tandis qu'à Trysil le nombre de pile reste le même.

Pour les deux autres variables, nous observons que les courbes de prédiction ont une plus grande pente dans le cas de Grue que dans celui de Trysil. Pour la variable jeune forêt avant la première éclaircie, plus ce peuplement est présent dans le carré, plus on trouve de pile. C'est le contraire pour les tourbières, plus on en trouve dans un carré, moins on trouve de pile (Figure 19).

Discussion

Les comparaisons des moyennes et des modèles montrent qu'il y a un impact de la clôture à Grue. Ce qui est important de noter, c'est que cet impact est plus important que les variables environnementales utilisées par l'élan pour sélectionner son habitat (Figure 20). Cet effet est renforcé par le fait que les tendances des variables significatives (Figure 20-21) sont cohérentes avec la littérature (H. K. Wam et Hjeljord 2010 ; Nikula et al. 2021). Cela démontre que la barrière est le facteur environnemental le plus influent sur la présence ou non d'élans parmi les variables que nous avons sélectionnées. Ainsi, la mise en place de barrières anti-carnivores empêche significativement les élans d'entrer dans la zone de pâturage.

Bien que les résultats tendent aussi à valider la deuxième hypothèse indiquant que retirer la barrière pendant l'hiver n'entraîne pas de phénomène de fragmentation, il est important de prendre en considération la migration de certaines populations d'élans. Dans le cas de notre étude, Grue est connue pour avoir une population d'élans qui reste en permanence dans la région. Cependant, Trysil, une région où la neige est abondante, est une zone où la population d'élans est très faible pendant l'hiver car les élans migrent vers la Suède.

De plus, les conditions environnementales telles que la lumière et les prévisions météorologiques, la végétation au sol, la qualité du travail et l'investissement des participants peuvent avoir un impact sur la détection des piles, et donc la précision des résultats. Enfin, après avoir trouvé une pile, il peut aussi être difficile d'identifier l'âge de la pile et l'animal qui l'a fait. C'est pourquoi nous avons maximisé notre précision avec la méthode de recherche dans le sens des aiguilles d'une montre puis dans le sens inverse et l'utilisation du formulaire qui permet de prendre des photos et d'éditer nos résultats a posteriori si nécessaire.

Avec les résultats obtenus, nous pouvons alors émettre différentes hypothèses.

Le fait de laisser la clôture pendant l'hiver pourrait exercer plus de pression sur celle-ci en raison des animaux qui la traversent. Le matériau serait davantage sollicité et se dégraderait plus rapidement qu'à Trysil.

Ainsi, bien que le fait de laisser la barrière en place pendant l'hiver n'entraîne aucune charge de travail liée au démontage et au remontage de celle-ci, il est possible que cela crée une charge d'entretien potentiellement plus élevée pour la remettre en état au printemps. Cela pourrait même avoir un impact sur la qualité de la barrière et donc qu'elle soit moins efficace contre les carnivores si cet entretien n'est pas fait correctement.

Nous pouvons également supposer que la suppression de la barrière pendant l'hiver entraînerait des phénomènes de facilitation entre les élans et les moutons. La présence de l'élan dans la zone

de pâturage pourrait générer des conditions environnementales favorable pour le pâturage des moutons. La myrtille est la végétation du sol la plus abondantes à Grue et Trysil durant l'été. Cette espèce végétale est en compétition avec l'herbe et l'empêche de pousser lorsqu'elle est en trop grande quantité. En se nourrissant de myrtilles durant l'hiver l'élan pourrait réduire l'impact de la myrtille sur l'herbe et ainsi facilité la pousse de celle-ci et donc maintenir une quantité de nourriture suffisante pour les moutons aux fils des années.

A cause des ressources limitées pendant l'hiver, les élans vont donc se tourner principalement vers des jeunes pousses d'arbres et notamment des pousses de pins. Les dégâts entraînés peuvent ainsi mettre en danger la production de bois et donc les revenus des propriétaires qui détenait ces parcelles. Les dégâts causés aux résineux durant l'hiver est corrélé à la densité des élans. De ce fait, si les élans ont accès à une plus grande surface, leur densité diminue et donc leur pression de pâturage aussi. Retirer les barrières pendant l'hiver contribuera probablement à réduire les dommages locaux qu'ils causent aux arbres, et donc être bénéfique pour l'activité forestière.

Par conséquent, la suppression de la clôture pendant l'hiver n'est pas seulement une pratique qui favorise les ongulés sauvages, mais pourrait à terme favoriser aussi les agriculteurs et les propriétaires fonciers.

Conclusion

Les résultats obtenus valident les deux hypothèses. L'installation d'une barrière anti-carnivores pour protéger les moutons pendant leur pâturage estival a un impact sur la densité des élans. De plus, retirer cette barrière en hiver semble éviter la fragmentation de leur habitat. Cependant, ces résultats peuvent être remis en question pour différentes raisons. Notre méthodologie a comparé deux pratiques différentes réalisées dans des environnements différents. En effet, Grue a une activité forestière plus intense que Trysil, ce qui donne des forêts de structure et de composition différentes. Cette différence fait que les populations d'élans ne sont pas non plus comparables. A Grue, la population a tendance à rester sur place, alors qu'à Trysil, elle migre vers la Suède pendant l'hiver. La manière dont les données ont été collectées joue également un rôle dans les résultats obtenus.

La méthode utilisée nous permet d'avoir une idée relativement précise de la densité des grands herbivores, en particulier des élans. La méthode de comptage des piles fécales est relativement simple mais elle nécessite une certaine expertise de la part de l'observateur, ce qui aura ensuite un impact sur la qualité des résultats obtenus. La précision des résultats dépend des observateurs et de la qualité de leur travail.

De plus, les résultats de cette étude nous permettent de soulever de nouvelles hypothèses sur l'intérêt de s'intéresser à la gestion de ces enclos afin d'entraîner des répercussions bénéfiques pour l'environnement, les agriculteurs et les propriétaires forestiers. Si le coût de l'entretien des clôtures ne sera pas étudié, l'INN analyse actuellement l'impact du pâturage du bétail en forêt. Toutes ces recherches, y compris celle-ci, pourraient ainsi permettre l'adoption de pratiques agricoles adaptées au système dans lequel elles s'inscrivent. L'agriculture et l'environnement sont étroitement liés et la prise en compte de tous ces facteurs conduira à un territoire durable permettant la conservation des pratiques ancrées dans l'agriculture norvégienne.

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1 Introduction

Although Norway has little arable area (3% of the land surface), it has a lot of uncultivated land such as mountains and forests. Thus, many farmers use the arable land for production of winter fodder and practice outdoor grazing in forests and mountains during summer (Strand et al. 2019). The vulnerability of livestock to predation when grazing unattended on uncultivated land is a big challenge in Norway, because it is home for four large carnivore species. With agriculture being one of the sectors generating the most conflict with these carnivores, brown bear (*Ursus arctos*), wolverine (*Gulo gulo*), wolf (*Canis lupus*), and lynx (*Lynx lynx*) were nearly extinct by the end of the 19th century (Asheim et Mysterud 2004).

The estimated population size of carnivores in 2021 in Norway by those responsible for the dissemination, operation and development of the national monitoring program for predators (RovData) are estimated at 160 bears, 386 wolverines, 125 to 129 wolves and 284 to 403 lynx.

The conservation of these species has been enabled by legislation issued in 2004 and 2011 known as the Carnivore Settlements. One of the resulting management actions was the establishment of Carnivore Management Zones (CMZ), defining protection areas for carnivores where populations are allowed to reproduce and where they are maintained at a threshold level for the species as defined by the legislature. Outside of the CMZs, the four large carnivore species are reduced by license hunt and damage-preventing culling. Each carnivore has an assigned CMZ and several CMZs can overlap, in total they represent 55% of the country's surface (Strand 2016). The areas where sheep and cattle are grazing during the summer can therefore be found in one or more CMZs, and 30% of sheep farmers are in one of these zones (Strand 2016). To cope with this, farmers therefore need to implement methods to protect their livestock.

The Hedmark region in western Norway is where the CMZs of the four species overlap (Strand et al. 2019). In the municipality of Grue and Trysil some sheep farmers decided to form a Local Grazing Association (LGA). This allowed them to set up an anti-carnivore enclosure in which they can put their sheep during the summer. However, Grue and Trysil manage their fence differently. Trysil dismantles the fence during the winter while Grue leaves the fence in place all year round.

The construction of these enclosures allows the sheep to graze safely in the forest, and thus promotes a grazing-based system. However, wild ungulates living in those forest are adapted to an environment where the main food resource is considered as browsing materials. Moreover, if it prevents carnivores from entering the grazing area it also might make it difficult for other mammals such as ungulates present in this country to enter as well. Although most ungulates' first behaviour is to jump fences (Harrington et Conover 2006), these protective devices for livestock may represent factors of fragmentation of their habitat (Scott 1992) and thus a segregation of their food resource.

Therefore, the Inland Norway University of Applied Sciences wanted to assess the effect of those fences by means of fecal pellet group counts. A count was therefore carried out from May to June 2022 to know if anti-carnivore barriers put in place to protect livestock in the forest constitute habitat fragmentation factors for large herbivores and furthermore, can this impact be mitigated depending on how the barrier is managed.

We will first explain the wild herbivores-boreal forest system during winter allowing us to understand why the implementation of such a barrier a risk for these species can be. Then the

methodology applied to this study will be developed followed by the results obtained and the discussion of these.

2 The winter herbivore activity in boreal forest

2.1 Conceptualization of the herbivore/forest system

To clarify the terms used in this part, the CIRAD animal science dictionary defines:

- Browser (or concentrate selector) as herbivores choosing the richest and most easily assimilated foods and feeding mainly on trees: leaves, flowers and fruits.
- Grazer as herbivores eating fibers, feeding mostly on grasses.

Although lignin can be considered as such, only the parietal compounds (cellulose and hemicellulose) will be called fibers. *Figure 1* below shows the characteristics of browsers and grazers.

Table 3.1 Summary of characteristics of browse and grass used for the generation of predictions of morphophysiological differences between browsers and grazers. The functional relevance (FR) code links these predictions to the following tables. See text for more detailed explanations and references

Subject groups	FR	Characteristic	Browse	Grass
Growth pattern/location	A1	landscape	forests/spatially more structured	open
	A2	growth pattern	at different heights	mostly close to ground
	A3	nutritional homogeneity of a 'bite'	less	more
Chemical composition	B1	protein content	higher (including nitrogenous secondary compounds)	lower
	B2	fibre content	lower but more lignified	higher but less lignified
	B3	pectin content	higher	lower
	B4	secondary compounds	more	less
Physical characteristics	C1	abrasive silica	less	more
	C2	adhering grit	less	more
	C3	resistance to chewing	less	more
	C4	fracture pattern	polygonal	longish fibre-like
	C5	change in specific gravity during fermentation	less	more
Digestion/fermentation	D1	overall digestibility	lower	higher
	D2	speed of digestion	fast	slow

Figure 1 : J.Gordon and H.T. Prins, The ecology of browsing and grazing 2008

2.1.1 The link between physiology and diet

Leporidae and Cervidae are said to be allo-enzymatic (whose enzymes are produced by other organisms). They digest through fermentation processes enabled by bacteria. In Leporidae, digestion is mainly in the cecum and in Cervidae, in the rumen. Phasianidae, on the other hand, have an auto-enzymatic digestive system (they produce their own digestive enzymes) (Cheeke et Dierenfeld 2010). Another possible distinction can be made in relation to the size of the individuals and thus their metabolism (Redjadj et al. 2014). Large herbivores (in our case Cervidae) can eat a large amount of low quality food even if at the single-bite scale, differences can be observed between grazers and browsers (*Figure 1*).

Conversely, small herbivores (Leporidae and Phasianidae) require less food but a high nutritional quality that they are able to select (Arsenault et Owen-Smith 2002; Redjadj et al. 2014).

In ruminants, other more precise physiological differences can be evoked. They involve, in particular, the more or less important development of salivary glands, the structure of the skull and the oral apparatus, the size of the rumen, the ratio of the size of the animal / length of the intestine (*Figure 2 and Figure 4*). The identification of these characteristics allowed R.R. HOFMANN at the end of the 20th century to publish an article leading to a classification of ruminants in 3 categories:

"Concentrate selectors (CS)" or "Browsing species" = They cannot tolerate large amounts of fiber in their diet. They mainly consume plants with high cell and lignin content (like buds, young stems or leaf), and low wall content. They produce more saliva than grazers because the compounds are more soluble, and they have a longer and more agile tongue as well as lips, which allows them to sort their food. They have a fast fermentation rate which implies less rumination and feed in small quantities but very often. Thus the caecum / rumen ratio is higher. Indeed, the lower fermentation rate of their rumen induces a higher proportion of unfermented food which will be taken care of by the caecum. In addition, because of their low fiber diet, they have a short gut length in proportion to their body size.

"Grazers or roughage feeders (GR)" = They feed mainly on grass, which is a fibrous food with little lignification, and select their food very little. Their head is therefore smaller and wider, with a small mouth. Their tongue is small and thick with small lips (*Figure 4*). They have a larger, more complex rumen with a longer retention time to digest a high cell wall diet. The presence of more fiber in their diet also implies a longer gut length than SCs compared to their body size. However, their cecum is smaller because rumen fermentation processes are longer and therefore more efficient.

"Intermediate feeders (IM)" = They are adapted to both grazing and browsing and modulate their diet between the two depending on plant availability. These changes are usually seasonally timed. They feed less frequently than SCs but more than GRs and hold a wide variation in the amount of fiber in their diet depending on the species.

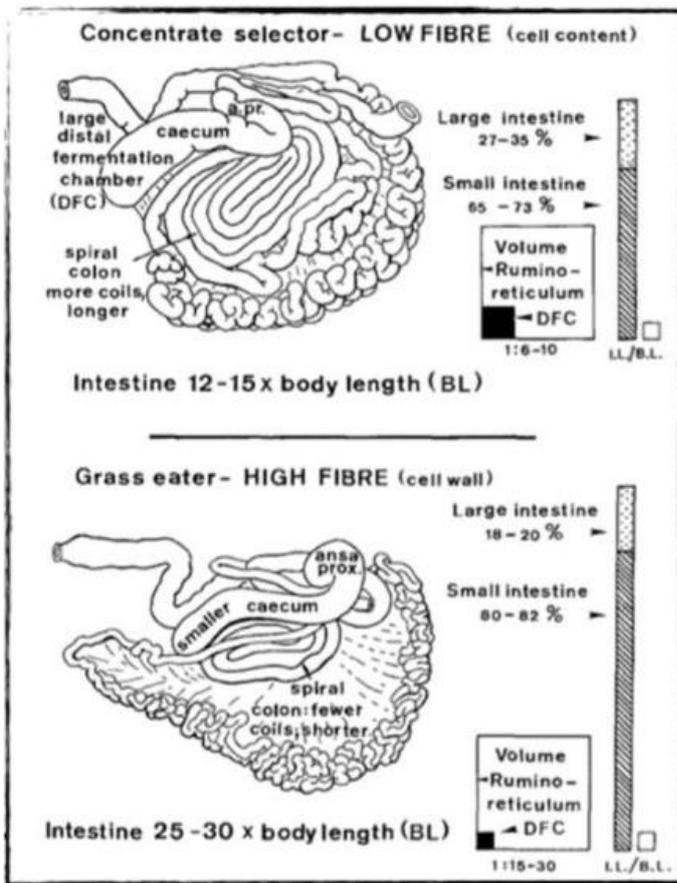


Figure 2 : Representation of the intestines of grazers and browsers

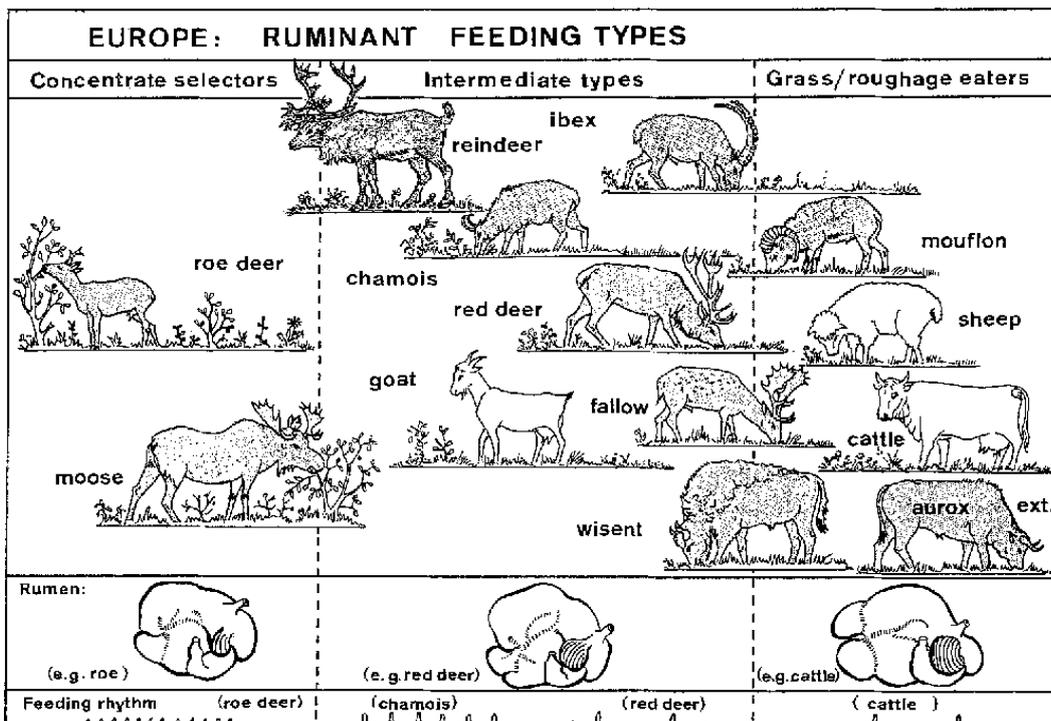


Figure 3 : Classification of ruminants by feed type

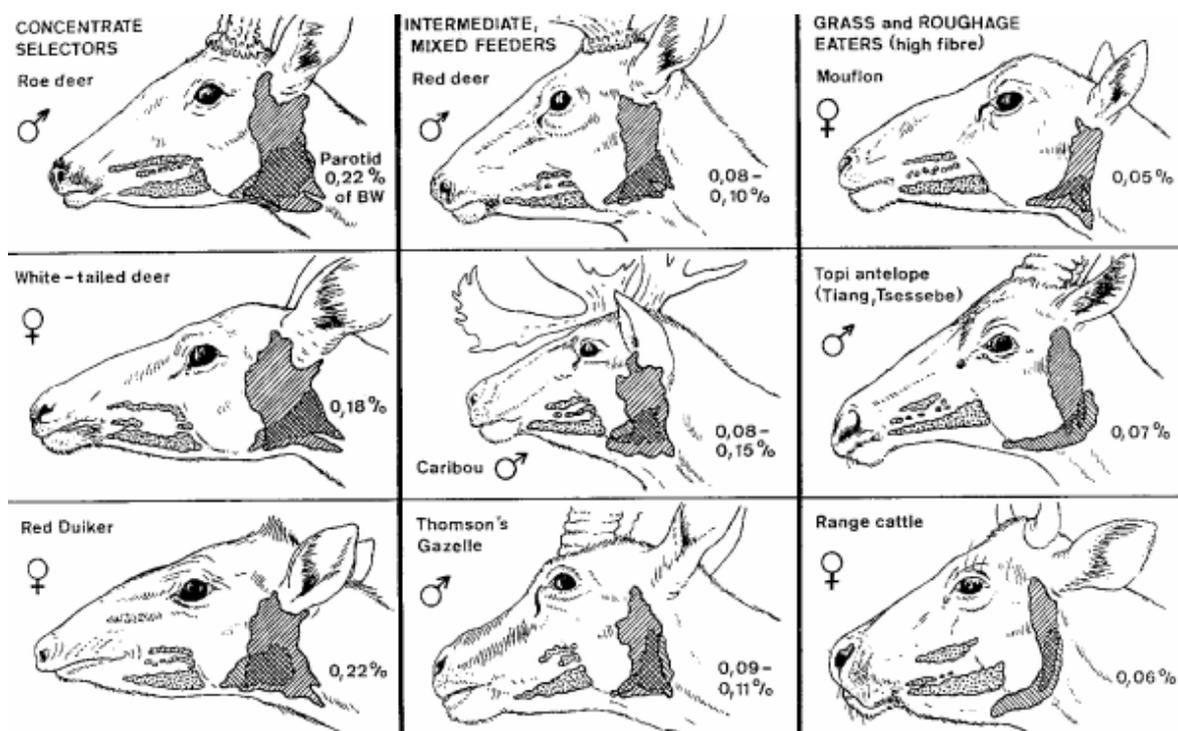


Figure 4 : Physiology of the oral organ of herbivores according to their category

Comparative topographic representation of salivary glands (from left to right: buccal, mandibular, parotid) in 9 ruminant species from 3 types of diet. The percentage of the animal's weight of the parotid gland is also represented

Published in 1989 this article *Evolutionary steps of ecophysiological adaptation and diversification of ruminants: a comparative view of their digestive system* has subsequently been cited and used as a reference in ruminant studies many times (Tixier et Duncan 1996; Gebert et Verheyden-Tixier 2001; Storms et al. 2008; Mysterud et al. 2010; H. Wam 2004; Lilleeng et al. 2018; Spitzer 2020; Pfeffer et al. 2021).

Thus, moose and roe deer are considered CS and red deer MI (Figure 3).

Although they are not ruminants, mountain hares (*Lepus timidus*) are also considered MI (Hulbert, Iason, et Mayes 2001). Phasianidae, on the other hand, are not considered herbivores but omnivores, although for the majority of their lives they possess a herbivorous diet (Summers et al. 2004; Wege et Kastdalen 2008).

Each of these species has a diet and thus a feeding niche that is dependent on their physiology, particularly their digestive systems (Hofmann 1989; Cheeke et Dierenfeld 2010).

However in Hoffman classification, the roe deer is considered to be more of a browser than the moose. However, it is an animal that is known to adapt its diet to the seasons and habitat, characteristics that are present in MI (Cornelis, Casaer, et Hermy 1999). Red deer too are subject to this type of contradiction. Sixty percent of its diet consists of low-fiber foods and the rest is grass. It has a mixed diet, but little change is observed according to the seasons. The proportion of fibrous or woody food remains relatively equivalent with a high proportion of woody compounds. Thus, it could also be considered as a SC (Gebert et Verheyden-Tixier

2001). In addition, this classification only concerns ruminants and does not include other plant-consuming species.

Some authors therefore question this classification and propose an alternative based on a gradient from the most browsing of species to the most grazing (Gebert and Verheyden-Tixier 2001; Redjadj et al. 2014). Although morphology correctly describes which food types a herbivore will turn to, it will be more relevant in this synthesis to classify animals on a scale from "maximally avoids grazing" to "maximally avoids browsing".

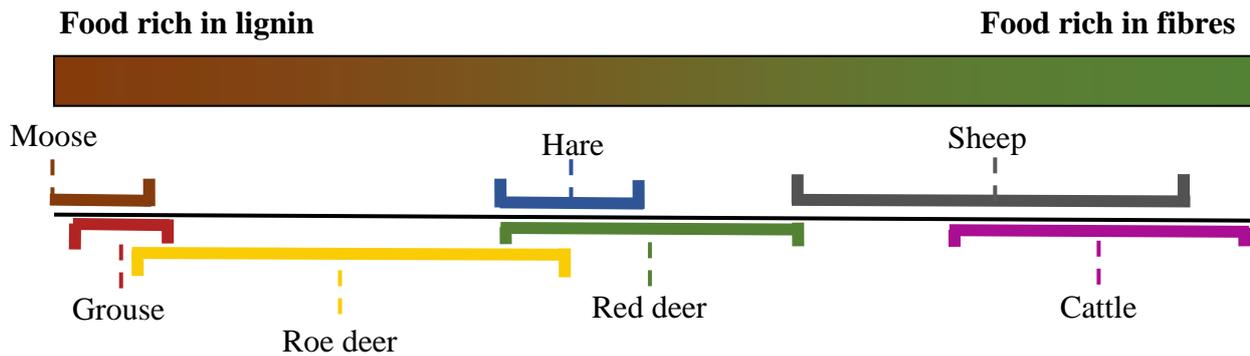


Figure 5 : distribution gradient of herbivore diets in the boreal forest

As an example it is possible to illustrate the gradient from food rich in lignin to rich in fibers (Figure 5). This makes it possible to add grouse and hare and to get rid of the MI class. Nevertheless, the placement of the species in relation to each other and the distance between them is not very precise in the case of this synthesis. On the other hand, this diagram makes it possible to easily expose the type of food that a species will consume, but also the diversity of their diet. Moreover, we put ourselves in a framework in which we know their exact diet and the way they feed in the given environment i.e. the boreal forests. The limitation of this scheme is that it is only valid for herbivores in a given biome, here the boreal forest, that is dominated by non-graminoid, lignin-rich plant species.

Hoffman's classification was a major step forward in the understanding of herbivore diets, even if it has some limitations, it is a great tool to understand how herbivores may interact.

2.2 [Winter, a difficult period for herbivores](#)

During the winter, the snow cover can reach a depth of 50cm. Accessibility to food thus becomes different for different species for several reasons. The first is simply due to winter and low temperatures that imply a dormant phase in most plants (Arsenault et Owen-Smith 2002). Secondly, the depth of the snow cover can change the accessibility to food, and in particular the height at which animals will feed. Snow can prevent access to lower vegetation but can also provide access to higher vegetation (Arsenault and Owen-Smith 2002).

2.2.1 Factors influencing feeding niches

Factors such as palatability, availability of resources, energy allocated to accessing them and what they will yield later are important in understanding the mechanisms that lead to the creation of a feeding niche. This niche can therefore be determined by several criteria depending or not on the animal. In general this is explained by the optimal foraging strategy. This strategy corresponds to the way in which animals maximize their energy intake per unit of time spent foraging, according to the various constraints mentioned above. Thus, they are looking for a food that will provide more energy than it will cost them to consume it (Rozen-Rechels et al. 2015). During the winter it is difficult for animals to access high quality food in the boreal forest, due to the cold and/or deep snow cover. Only resinous trees and some shrubs can be used as a food source (Hulbert, Iason, and Mayes 2001; Arsenault and Owen-Smith 2002).

Rowan is the primary species selected by moose, followed by willow and aspen. However, these species are rare, partly due to overbrowsing, and partly due to silvicultural measures that favour the coniferous species Scots pine and Norway spruce for wood production. The only abundant deciduous tree species is birch, which is not as attractive for moose as the species mentioned above. Due to the scarcity of preferred tree species, moose browse mostly on pine in young forest stands during winter. Browsing can damage these production trees, with economical consequences for the forestry sector. The same is true for hares, where the proportion of young branches, softwood thorns, and shrubs in the diet is inversely correlated with the presence of grass or berries. Grouse species favor leaves and berry bushes in the non-winter period, but feed almost exclusively on pine needles during the dormant season (Hulbert and Andersen 2001; Hulbert, Iason, and Mayes 2001; Summers et al. 2004; Wegge and Kastdalen 2008). Red deer turns to resinous and more woody products during winter than in the other seasons (Storms et al. 2008). For the roe deer, which has a more varied diet, the difference is in the species consumed, as they will turn to resinous rather than deciduous trees, and also to heather and berry bushes (Tixier et Duncan 1996). Although species such as red deer, roe deer, and hare readily adapt their diets, these changes are primarily due to a decrease in the food resources preferred by each species during the winter. They will therefore turn to a diet richer in lignin and less rich in fiber during this period. During winter, herbivores prefer to turn to low quality and/or limited quantity foods (Hulbert and Andersen 2001).

2.2.2 Niche overlap and food competition

Red deer and roe deer share the same habitat and resource. However, the great diversity of the roe deer diet limits the overlap of their feeding niche (Gebert and Verheyden-Tixier 2001). Red deer and moose share little in the way of diet and do not necessarily concentrate in the same areas (Gebert and Verheyden-Tixier 2001). Because they do not share the same habitat, the possible overlap of their feeding niches is further reduced.

Although there is a potential overlap in the feeding niches of some species, this does not directly involve competition (Arsenault and Owen-Smith 2002). Indeed, two species can coexist without antagonistic effects on each other (Hulbert and Andersen 2001). One possible explanation for this phenomenon is the "feeding-height separation hypothesis". This hypothesis assumes that the size of an animal will condition the height at which it will feed, and thus create a stratification of resources within a system where herbivores cohabit (Dutoit 1990).

However, hare and deers may share the same feeding niches. Especially in winter, the feeding-height separation hypothesis does not apply due to the presence of a large snow cover. Since hares do not sink into the snow, they have access to resources as high as roe deer, red deer or moose can reach. However, this does not necessarily mean competition. Moose will feed on thicker stems than the hare. Only roe deer and red deer have a strong overlap in

their feeding niche with hare because they consume stems of the same diameter (Hulbert and Andersen 2001).

Grouse often live in bog areas of old-growth pine forests with low densities of bilberry (Summers et al. 2004; Wegge et Kastdalen 2008). Thus, they may share their habitat with moose. However, although they both feed on pine, there is no evidence of competition between moose and grouse.

3 Research question and hypothesis

The implementation of regulations for carnivores' conservation has led to the maintenance of at least one of the species in 1/3 of the European territory, especially in Norway (Strand et al. 2019). Through Decision 337 of the proposal.174S (2003-2004) and Decision 687 of Proposition 163S (2010-2011) Norway as created the Carnivores Management Zones to maintained at a threshold level. Trysil and Grue are in a specific location where all the Carnivores Management Zones are overlapping and since a common practice of farmers is to put animals in the forest during the summer, they had to build a carnivore proof fence. To achieve that goal, farmers from each location created a Local Grazing Association that allows them to access subsidies for fence maintenance and carnivore losses, in return for an annual review of their production (Strand et al. 2019).

On the other hand winter conditions and the composition of boreal forests during this period cause wild herbivores to adapt and change their respective feeding niches. This period is marked by a stronger overlap of these, and thus leads to a system with stronger interactions. The use of the word competition is questionable, because it requires such a density of herbivores that the resource becomes limited. It depends on particular factors, but in the presence of these different conditions, the occurrence of competition cannot be excluded especially if the area is restricted by some fences and therefore, concentrate herbivores in specific area.

However, both areas have a different way to manage their fence. During the winter, when sheep are not grazing Grue let the fence up while Trysil dismantle it.

The Inland Norway University started in 2021 a project called CarniForeGraze (Grazing in Carnivore Forests). The purpose is to study the potential of using carnivore-exposed forests in south eastern Norway for livestock grazing in combination with forestry and large game hunting, while taking into account biodiversity of plants and pollinators. This year the question about how those fences impact wild animals was studied through different aspect. One of them is :

Does the fences put in place to protect sheep in forest again carnivores is a factor of habitat fragmentation for wild ungulates? Plus, if such an impact exist, does the way the fence is managed can mitigate this factor?

We expect the Grue fence to have a negative impact on moose presence in the grazing area. However, we expect that Trysil will not show such an effect, indicating that the removal of the fence will prevent a factor of habitat fragmentation.

4 Methodology

4.1 Study areas

4.1.1 Grue

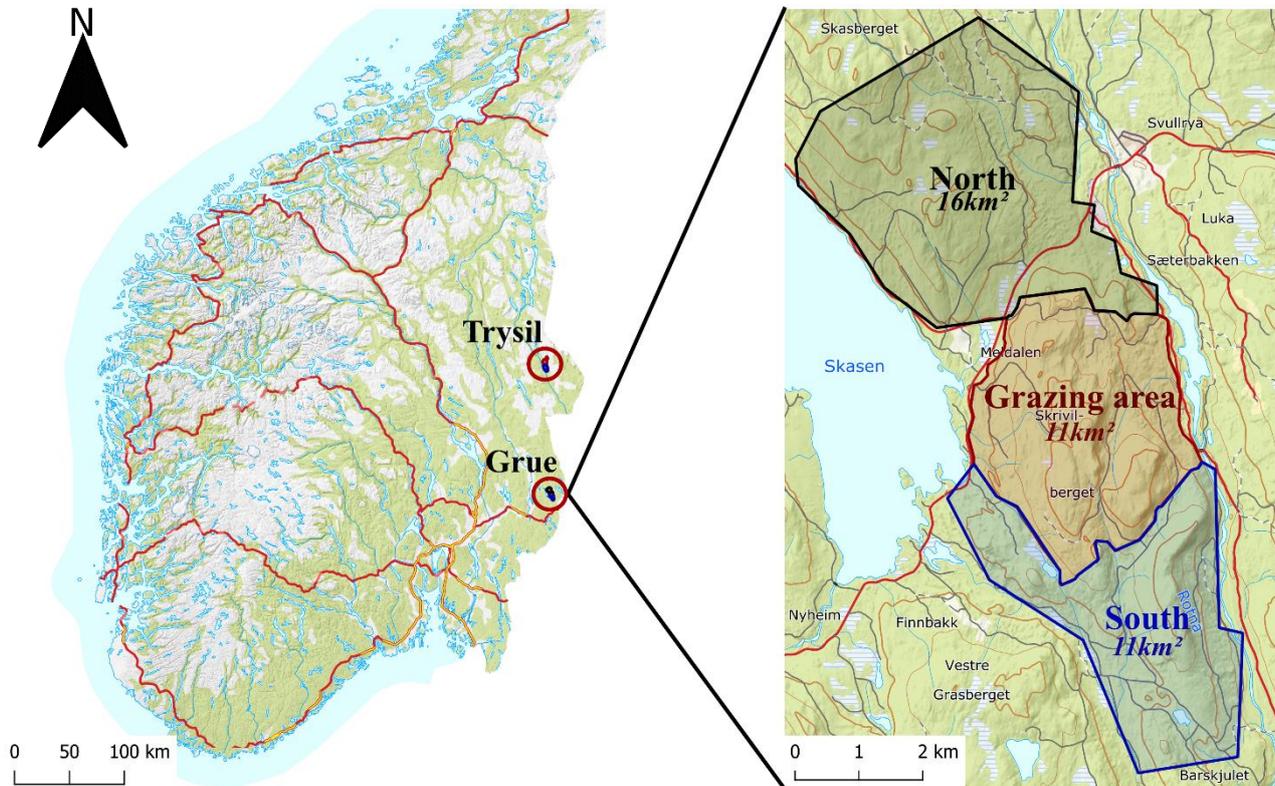


Figure 6 : Area delimitation in Grue

This study area ($60^{\circ}22'08.9''\text{N}$ $12^{\circ}23'54.9''\text{E}$) is located in eastern Norway in the region of Grue, close to the Swedish border. During the winter, farmers in Grue keep the fence up.

The red zone delineates the enclosure and the two other zones the control zones (Figure 6). The latter were chosen to have a similar environment in terms of vegetation and topography. They also follow the main roads (red lines) allowing quick access and limiting the bias of results caused by a possible fragmentation of the habitat. We decided not to add a control area to the east of the barrier because we felt that the road and river would have impacted the effects of the enclosure too strongly.

All three zones are forested areas with high forestry activity. The dominant forest stage is "young forest at thinning age" with a majority of spruce. The dominant species for the ground vegetation is mosses and the elevation varies between 274 and 506 meters with an average of 373 meters.

4.1.2 Trysil

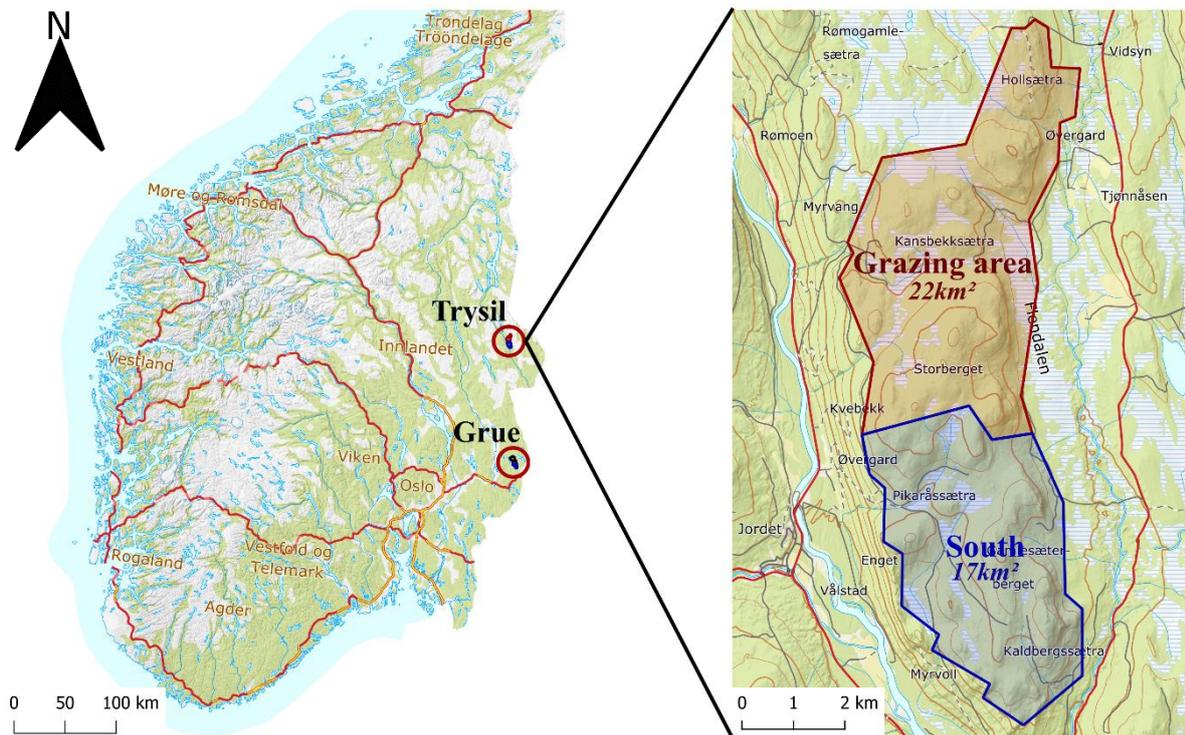


Figure 7 : Area delimitation in Trysil

This study area ($61^{\circ}27'32.8''\text{N}$ $12^{\circ}11'51.5''\text{E}$) is also located in eastern Norway in the Trysil region, close to the Swedish border but about 100 km north of Grue. Trysil corresponds to the area where the fence is dismantled during the winter.

The red zone corresponds to the enclosure and the blue zone to the control zone (Figure 7). The blue area was chosen to have a similar environment in terms of vegetation and topography. To the north of the enclosure, the environment is mostly bogs, an environment that ungulates rarely frequent (Nikula, Heikkinen, et Helle 2004). We therefore decided not to include a control zone in order to avoid a bias related to the low frequency of use of this environment. Unlike Grue, this study area has only one control zone, to the south.

Both zones are forested areas with low forestry activity. The dominant forest stage is "old growth forest" with a majority of spruce. The dominant species for the ground vegetation is shared between mosses for the grazing area and bilberry for the South. The altitude varies between 596 and 890 meters with an average of 756 meters.

4.2 Ungulate Density Estimates for Winter 2021-2022

4.2.1 Counting

Because direct counts of wild-living individuals is not possible, we used an indirect method by counting fecal pellet groups. This method is frequently used in forest areas to estimate ungulate populations (Marques et al. 2001). There are two possible ways to conduct this count. Either all pellet groups (old and new) are counted, or only new pellet groups are counted. The first method, called Faecal Standing Crop (FSC), requires knowledge of the persistence period of the pellets in a given environment. The second method, Faecal Accumulation Rate (FAR),

requires knowledge of the date that the area was cleaned of pellets and therefore the date that they accumulated (Smart, Ward, and White 2004).

In this study, the use of an indirect method was also preferred to have a better description of the habitat use of the ungulates during winter. Direct methods generally provide an estimate of the population, but not necessarily how individuals use their home range (Marques et al. 2001). The FAR method was chosen. It provides a more accurate estimate of population and land use than FSC, which can lead to overestimates (Månsson, Andrén, et Sand 2011). Nevertheless, FSC may be more interesting in cases of low ungulate density because it allows limiting the number zero-counts, which are difficult to handle in data analysis. In addition, estimating the period of persistence of excretions requires a protocol to know it according to the types of environments in which the count would have been conducted. It was necessary to start the counting campaign as soon as possible, so the establishment of such a protocol was not feasible from a time point of view (Alves et al. 2013). The start date of the FAR period was set at October 10, 2021. This date corresponds approximately to the end of leaf fall and the beginning of the first snow, which marks the end of fall. This is also the date used for a similar data collection studying moose migration throughout the year (Zimmermann et al. 2022). Since this is the first time this fieldwork has taken place in the study areas, the sample plots had previously not been cleaned. Nevertheless, only pellet groups from after leaf fall were counted, i.e. any pellet group estimated before the winter of 2021-2022 was considered old. This allowed to simulate a preliminary cleaning of the area. More details about the ageing of the pellet groups is given in chapter 4.3.4

4.2.2 The technique used

The purpose of the study was to know how ungulates were distributed in our study areas. Thus, we decided to use a regular sampling scheme, with plots evenly distributed throughout the study areas.

Among the possible techniques we had to choose between transects or plots. The first technique can be carried out with a transect of defined width in which the counting will be done, or to make distance sampling by looking rather at the perpendicular distance of the pellet group compared to the line of transect. The second technique creates search units called sample plots that can be of different sizes, locations and shapes.

The use of transects to count the pellet groups did not seem to be suitable because it would not be possible to cover the search area homogeneously, so it was decided to use the plot technique. Moreover, the transect technique tends to be more accurate, but the increase in plot density and thus study area makes the use of plots just as relevant (Alves et al. 2013).

We choose the same study design used by Zimmermann et al. 2022 and Versluijs 2018. This consists of squares with five 100m² circular sample plots (radius 5.64 m), arranged like the five of a dice, with the outer edges being 50 m (*Figure 9*). The squares were distributed homogeneously across the study areas. A plot corresponds to a research zone and a square thus includes 5 zones. For data analysis, we later summed the information of the plots belonging to a square, and thus limited the occurrence of zero-counts in the statistical treatments.

4.2.3 Layout of squares

QGIS software version 3.26.2 (QGIS, 2022) was used to lay out the plots and squares in the study areas. The delimitation of the grazing and control areas were digitized on the screen using a national raster map as background. Within the limits, I inserted a hexagonal grid. This shape allows to have center points that are at equal distance from each other. The center points of the hexagonal grid cells were the middle sample plots of the squares, and the other four sample plots

belonging to the same square were arranged around this middle plot in NE, SE, SW and NW direction . The cell size of the grid was established according to three criteria:

- The workload that it would generate
- The proximity of the squares to each other
- To have enough data to do a relevant statistical work

After several tests, the final grid had hexagons of 125 000m². We decided to keep the same grid density for the Trysil and Grue zones rather than opting for the same number of squares (and therefore plots) in each zone (Figure , Figure). This allowed us to have a similar density of squares for both areas to maximize comparability. Each square is named from West to East by a letter and from North to South by a number, and then each plot has a number from 0 to 4 where 0 corresponds to the centre.

	Grue	Trysil
North	119 squares (595 plots)	
Grazing	88 squares (440 plots)	170 squares (850 plots)
South	80 squares (400 plots)	138 squares (690 plots)
Sum	287 squares (1 435 plots)	308 squares (1 540 plots)

Figure 8 : Square and plots repartition for each area

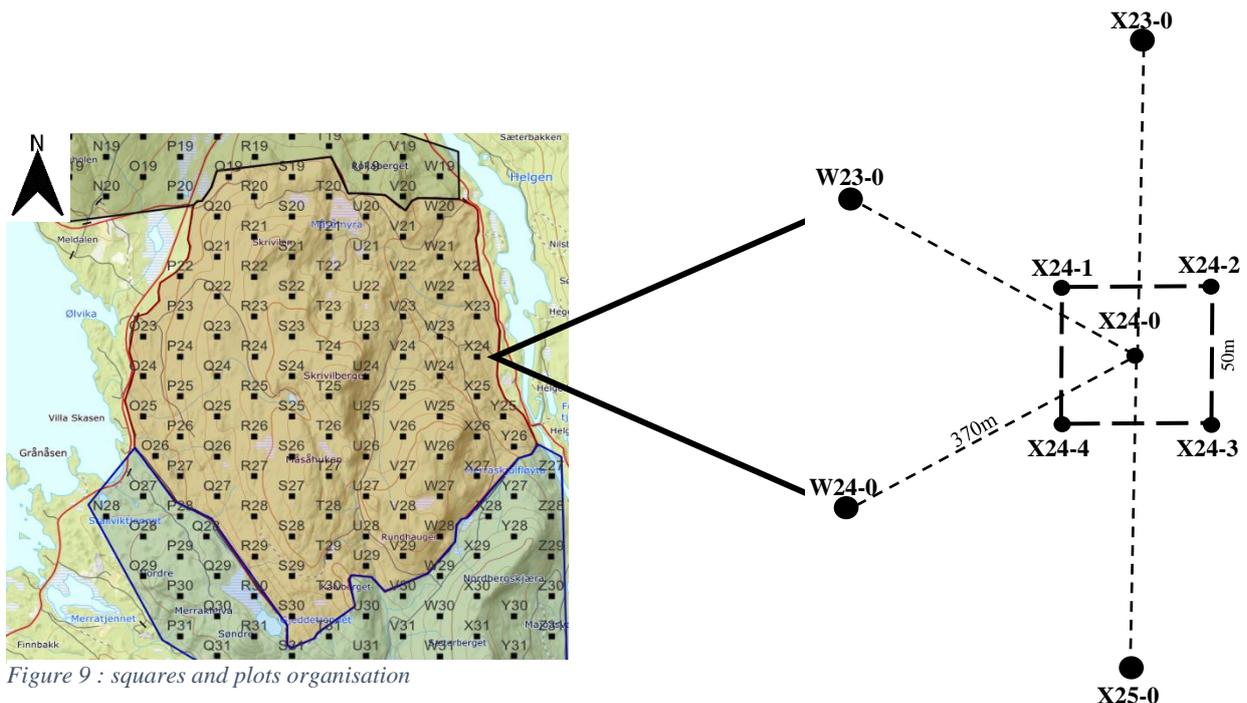


Figure 9 : squares and plots organisation

Once all the squares had been placed, it was necessary to check that they did not overlap the enclosure, i.e. that some of the plot in the same square were in two different zones. If this was the case, these squares were moved, just like when they were located on a road. The following methodology was applied to move the squares.

- Move the square 50m (one square length) to the North, if this is not possible, try to the East, then to the South and finally to the West.
- If the 4 previous options were not feasible, the square must be removed because otherwise it will be too close to another one and it will not be very useful

NB : the second condition has been applied only in Trysil on 5 squares among the 313 initially planned.

4.3 [The fieldwork](#)

4.3.1 [Composition of the teams and daily organization](#)

Twelve people including myself took part in the count. Each person had between 5 and 6 squares to do during the day. Their distribution was thought out according to the distance to be covered by car and the distance to be covered on foot with the difference in altitude. The goal was to optimize the trips by making them as short as possible while minimizing the effort related to the altitude. Most of the time the work during the day was done individually. Nevertheless, we sometimes worked in pairs, i.e. we worked on the same square but not on the same plots, in order to cover 11-12 squares during the day. In this way it was possible to cover a greater distance from the car when the roads did not allow easy access to some squares.

It was the Grue area that was done first during the months of May, once the ground had thawed so that the bamboo sticks used to mark the plot centre could be planted (part 4.3.5). The Trysil area being much further north, is a region where the snow melts in late May, so we realized the fieldwork in June.

4.3.2 [Using kobotoolbox](#)

KoboToolbox is a suite of free and open-source tools for field data collection. This suite includes a website (KoboToolbox) and a phone/tablet application (KoBoCollect). The website allows to create forms with filling conditions and different types of information input, but also to set up how the data will be exported from this form. Moreover, the website allows to visualize the information collected via the form available on the KoboCollect application and to edit the filled forms if necessary. This form allowed us to register the number of red deer, moose, and roe deer pellet groups, but also the forest composition and the presence of other species such as hare, capercaillie and black grouse.

4.3.3 [Species differentiation](#)

An initial group of 5 people including myself were trained by the study supervisor to identify the scat of the most common animal species found in the boreal forest:

- Roe deer
- Red deer
- Moose
- Hare
- Capercaillie
- Black grouse

All other people who joined the project were trained by one of the 5 people during a whole day. Via the form it was possible to add photos when we could not identify certain droppings. These photos were then discussed with the other team members and the supervisor to edit the form if necessary.

4.3.4 [Estimating the age of the pellet groups](#)

The differentiation between young (after leave fall in 2021) and old (before leave fall in 2021) was based on several indicators. The first indicator was the arrangement of the leaf litter relative to the pellet group. If the tree leaves were on top of the pellet group, it meant that the droppings were there before the leaves fell, and therefore before the end of fall. The boreal forests being mainly made up of coniferous trees, this criterion was of little use to us. The development of the vegetation, the appearance of the droppings, their consistency and disposition were the

criteria most often used. If the vegetation had grown through or around the pellet group, it meant that there had been a growth cycle after the pellet group was made, so the scat was from before the fall of 2021. If the pellet group looked too decomposed with fungus on it, very dry and crumbly or unstructured it was also considered too old. In addition, ungulates can have seasonally varying scat shapes. Scat that is less structured and looks more like dung means that it was made during the summer in the case of moose, so it was not counted.

4.3.5 Counting the pellet groups

To move between the plots we used the Norgeskart Outdoors application in which all the plots were loaded. Once we arrived on a plot, we switched to the KoboCollect application to fill in the form in the following way:

- 1- Placing himself on the center of the plot and recorded the GPS position
- 2- Since this is the first counting, a bamboo stick with the end painted in white has been placed on the center of the plot. This will allow to find the plot and to have the same circle and therefore the same working area for the next period of fieldwork
- 3- We setted up the rope on the stick which will allow us to know our distance from the center

NB: the working area is composed of a small circle of 1.78m radius (10m²) contained in a large circle of 5.64m radius (100m²) as below.

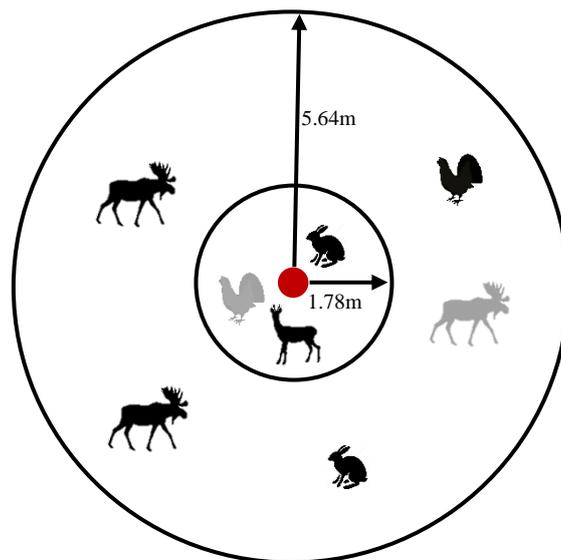


Figure 8 : Sample plot consisting of the inner 10 m² and the outer 100 m² circle. The animals are a hypothetical example of where pellet groups were found, with black indicating those found in the clockwise tour, and grey are those found in the counter clockwise tour.

4- First search clockwise

4a- We started clockwise to look for pellets of all species dating from this winter or younger in the small circle. We looked mainly for roe deer and other leporidae and gallinaceous species. It is rare that roe deer make pellet groups, so a careful search was needed

4b- Once finished, we made a search in the big circle always in the clockwise direction. This time we mainly looked for moose or red deer pellet groups. Any other excrement found in the large circle was also counted

4c- Then we filled out the form in KoboCollect and throw out of the big circle all the excrement found to clean the plot (you can find *Appendix 3* of how the form would have been filled following the Figure 8)

5- Second search counter-clockwise

5a- we repeat steps 4a and 4b

5b- Any new pellet group found had been added without considering the one from the first round.

5c- We filled in the form in KoboCollect and throw out of the big circle all the excrements found to clean the plot (you can find the *Appendix 3* of how the form would have been filled following the Figure 8)

6- Finally, we finished filling in the form

The purpose of counting clockwise and then counterclockwise is to maximize our chances of finding all the excrement. Sometimes, depending on the orientation of the sun and the vegetation, some droppings may not be visible from certain angles. This method also allows by its standardization to further limit the observer's bias.

Although large herbivores make pellet groups with an average of more than 50 pellets (Spitzer 2019), we decided to include pellet groups in the counts if they contained at least 20 pellets, to maximize the sensitivity of the method (Alves et al. 2013). Moreover, a pellet group was counted only when the majority of it was inside the large circle. Thus, for the case of piles that straddled the boundary of the great circle, we could easily determine whether it was counted or not.

4.3.6 [Vegetation Analysis](#)

In the same way as the identification of animal species, training was given to identify:

- The stage of the forest ("clear cut or regrowth", "young forest before first thinning", "young forest in thinning stage", "forest ready to be harvested", "old forest", "bog")
- The dominant tree species ("pine", "spruce", "birch", "aspen")
- The dominant species of the ground layer vegetation ("mosses", "blueberry", "crowberry", "cowberry", "lichen", "grasses")

The forest stage corresponds to the way the forestry sector categorizes forests. The other variables were chosen considering the species that are mainly found in Norwegian boreal forests (Wam and Hjeljord 2010). The estimation of the dominant species was done by visual observation.

4.4 [Data processing](#)

4.4.1 [Data cleaning](#)

The R software version 4.2.1 (Rstudio, 2022) was used to organize the data sets and to perform the statistical tests. Only the variables used to describe the habitat and the pellet group counts were kept. The calculation of pellet group densities for each species was obtained by dividing the number of pellet groups by the surface of a square in hectare (0.05ha) and by the collection period. The latter corresponds to the time interval between the date set at 10/10/2021

and the date on which the pellet groups were counted. The information from the 5 plots was grouped into one square as follows:

- The number of ungulate pellet groups were summed up
- The other species (hare, capercaillie and black grouse) were summarized in presence/absence.
- For the habitats (forest stand, dominant tree species and dominant ground vegetation), the most abundant data was kept. In the case of equality of quantity, the first in alphabetical order was chosen. Nevertheless, the respective quantities of each variable have been kept

In the *Appendix 1*, the list of retained variables is available.

4.4.2 Models creation

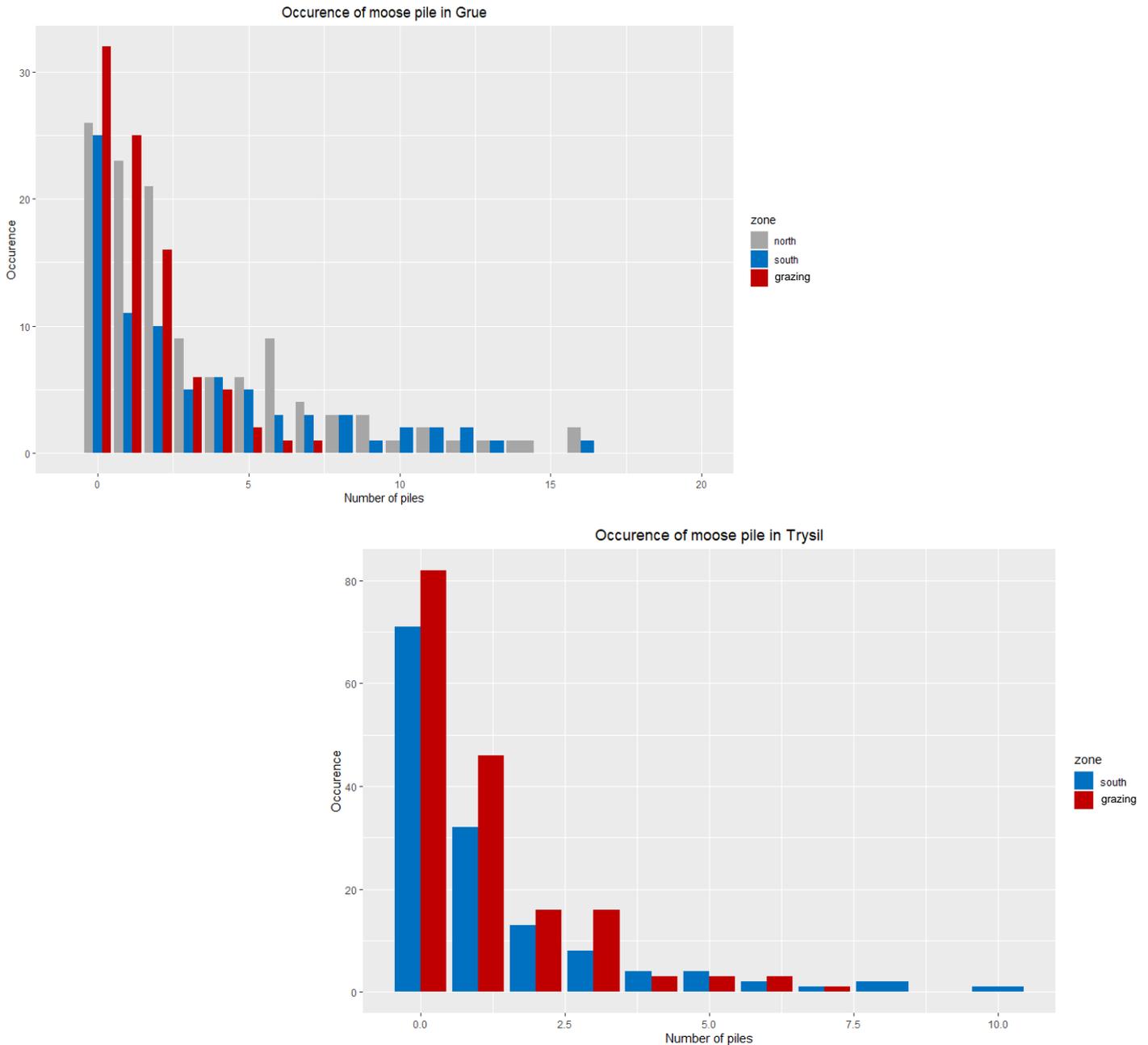


Figure 9 : Frequency distribution of moose pellet group in Trysil and Grue

In Grue, only 22% of squares had no pellet groups in the North, 36% in the grazing area and 31% in the South. For Trysil, the number of squares with no pellet groups represented 42% of the grazing area and 59% of the southern area. When data are collected by a counting procedure, they follow a Poisson distribution. However, due to the high proportion of zero data, it was chosen to consider that the distribution followed a negative binomial distribution, which reduced the overdispersion of the model (Figure 9).

The variables of interest for the model are:

1. Zone
2. Distance to roads
3. Altitude
4. Young forest before first thinning (number of plots per square that had young forest as dominant forest age class, 0-5, forest stand category)
5. Bog (number of plots per square that had bog as dominant habitat type, 0-5, forest stand category)
6. Pine (number of plots per square that had pine as dominant tree species, 0-5, tree species categorie)
7. Bilberry (number of plots per square that had bilberry as dominant ground layer, 0-5, ground vegetation category)

The use of pellet group density was not possible because the realization of a regression with a negative binomial distribution requires integer numbers. Thus, the variable studied is the number of pellet groups corrected with the time interval by using the offset when performing the regressions. The surface of the squares being all the same, the fact of not integrating it will not generate any difference of result.

A total of seven models have been tested for Grue and Trysil. The first one was an univariate model testing the effect of Zone variable. The following five others are multivariate models testing the effect of each variable from a same category, and finally a model with all the variable at once.

The choice of the variables was made according to what has the greatest impact on the presence of a moose in a given environment. Indeed, during winter, moose favor pine trees as food sources, especially in young forests, and avoid bogs (Nikula, Heikkinen, et Helle 2004; H. K. Wam et Hjeljord 2010). The variable corresponding to this forest age is young forest before first thinning. Although during winter access to ground vegetation remains difficult, we decided to include bilberries as a variable. In relation to the depth of snow, the latter is known to be an important species in the diet of moose even during winter (H. K. Wam et Hjeljord 2010).

The interest of adding other variables in addition to the area, was to be able to compare the size of the impact of it. We wanted to see if the area was a variable that would have more importance in the presence of ungulates than the environmental variables that determine the way they use the territory.

Then, the models were compared with their AIC and r^2 and the one with the smallest values was chosen.

5 Results

5.1 Environment description

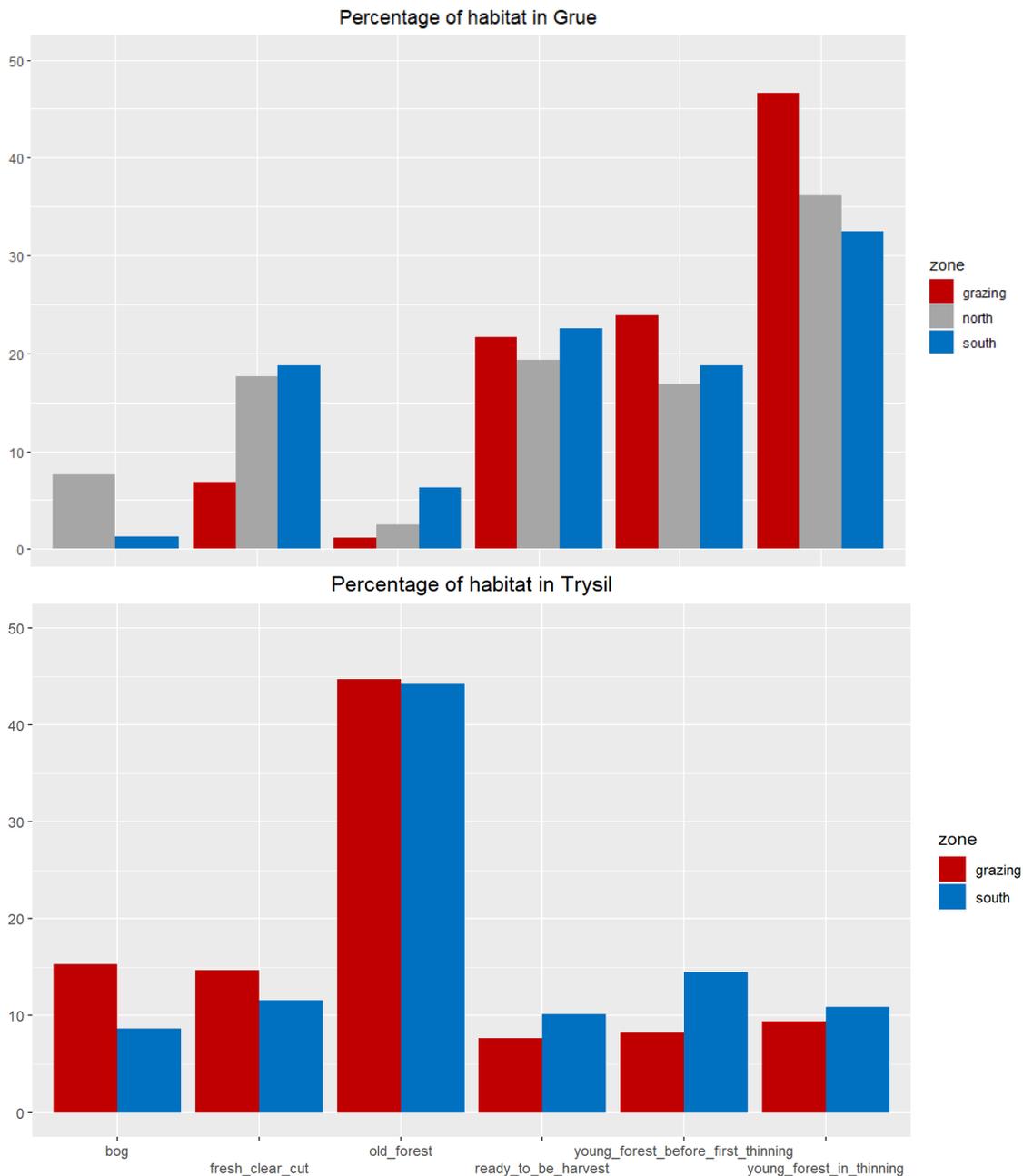


Figure 10 : Percentage of habitat in each area

Grue is an area where the forest is predominantly in the young forest in thinning stage for all three study areas. It can also be noted that the southern and northern areas are relatively similar in terms of habitat except for the bogs. The grazing area has a majority of habitats comparable to the other two areas, but for the less present this comparison is not possible. Generally speaking, we can summarize Grue by more than a third of young forest in thinning stage, and then a quarter of young forest before first thinning and ready to be harvest. It is therefore an environment where the forests are young.

Trysil has a majority of old forest. Contrary to Grue, it is possible to admit that the grazing area and the control area are similar. Moreover, the environment is composed of almost half of old forest, and then a balanced distribution of other forest stages.

It is therefore not possible to compare Grue and Trysil, nevertheless, the zone in each area can be considered similar although Grue has some differences (Figure 10).

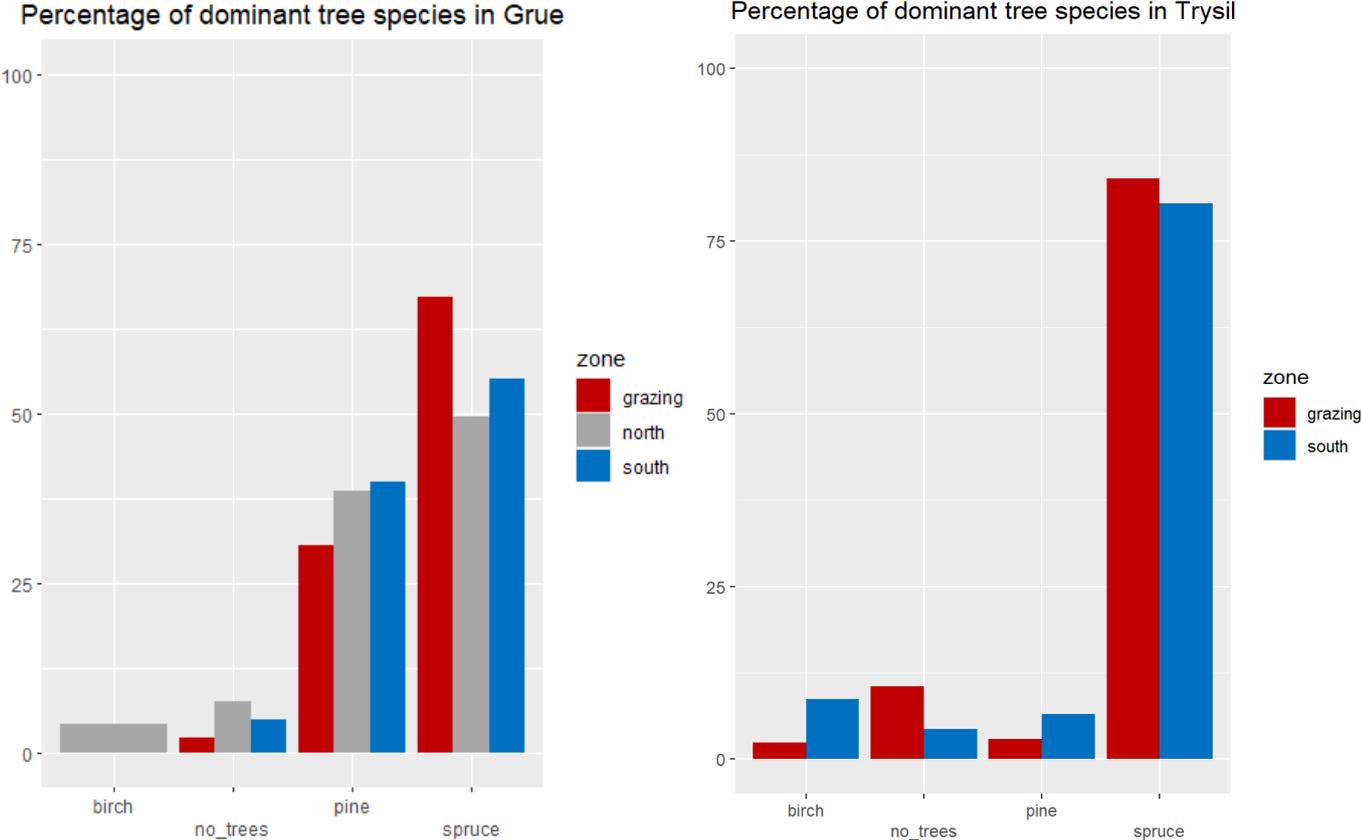


Figure 11 : Dominant tree species in each area

The dominant tree species for Trysil and Grue is Spruce. It represents about half of the species found in Grue and more than three quarters in Trysil. Grue also has a high proportion of Pine representing about one third of the tree species present. As for the forest stage, besides the dominant species Trysil has a very small amount of other dominant trees. Each zone has the same tendency and proportion of dominant tree, so we can consider that this variable is similar between the grazing and control zones (Figure 11). Looking at the number of dominant trees by forest stage, the most dominant environment at Grue is the young spruce forest in thinning stage representing almost 25% of the total environment. For Trysil, it is old spruce forest that dominates with a proportion of over 30% (Appendix 2).

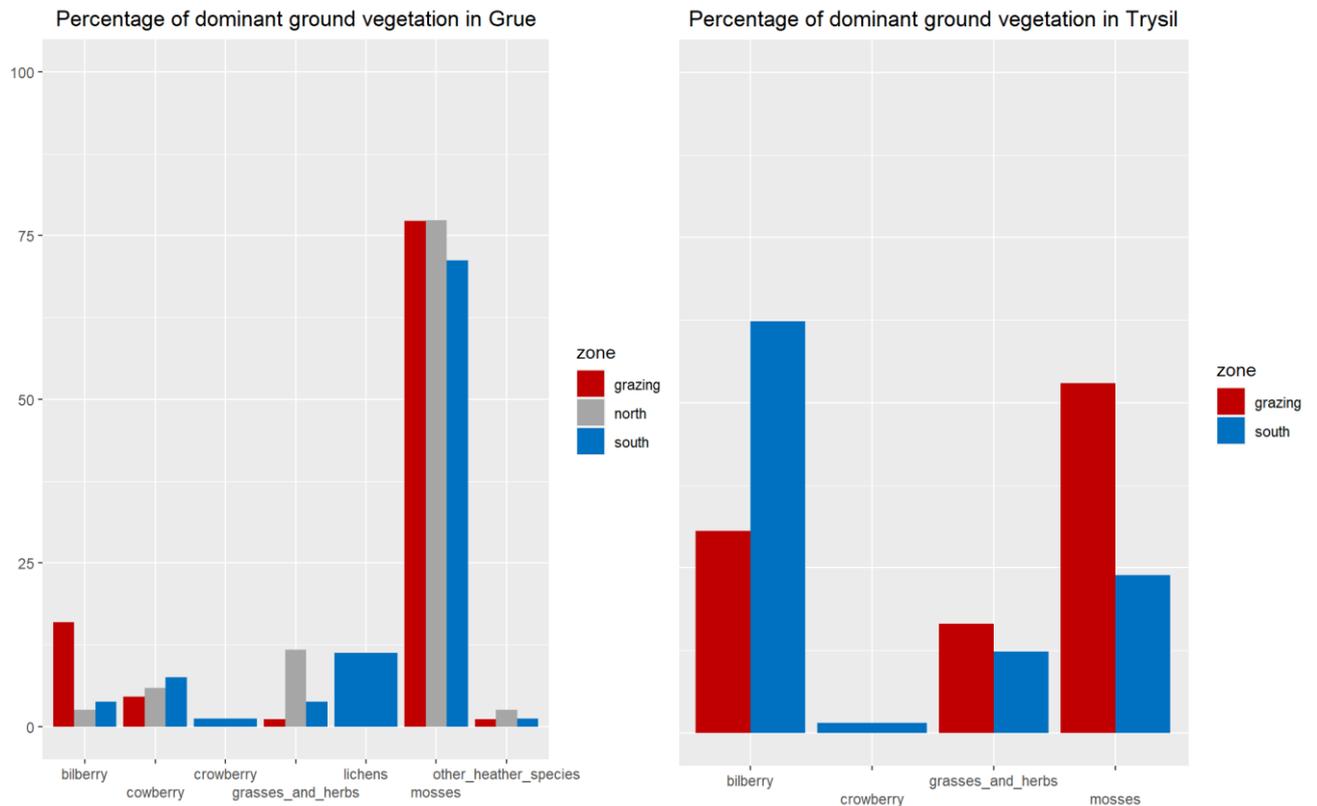


Figure 12 : Percentage of dominant ground vegetation in each area

In Grue, mosses represent three quarter of the of ground vegetation species. Therefore, the ground vegetation in Grue can be considered similaire outside and inside of the grazing zone because of the high proportion of mosses. For Trysil, mosses was the dominant species only in the grazing area. In the south we can observed a higher proportion of bilberry that reach 60% of the ground vegetation present. Thus, Trysil dominant ground vegetation can't be considered as similar (Figure 12).

5.2 Relative ungulate densities

5.2.1 Environment use

	Moose pellet groups	Roe deer pellet groups	Red deer pellet groups
North	424 163	16 7	1 15
Grazing	118 178	15 3	4 5
South	262	10	12
Total	804 341	41 10	17 20

Figure 13 : Number of pellet groups in Grue (blue) and Trysil (red) for each ungulates

The dominant species in Grue and Trysil is the moose with 93% of the total pellet groups find in Grue and 92% in Trysil. Even if Trysil represented a bigger area, less than half of what have

been found in Grue has been register there (*Figure 13*). The next figure (*Figure 14*) shows only moose forest stand use in both study area because of the low amount of the other two species.

	Bog	Fresh clear cut	Old forest	Forest ready to by harvest	Young forest before first thinning	Young forest in thinning stage	Total
North	8 7	98 7	3 66	52 24	154 25	109 34	424 163
Grazing	0 9	7 28	0 84	14 28	25 13	72 16	118 178
South	1	55	17	61	69	59	262
Total	9 16	160 35	20 150	127 52	248 38	240 50	804 341

Figure 14 : Number of pellet groups of moose in Grue (blue) and Trysil (red) in each forest stand

In Grue most of the pellet groups has been find in young forest with 31% of moose pellet groups in young forest before first thinning and 30% in young forest in thinning stage. However, in Trysil it's in the old forest environment that we found most of the pellet groups representing 44% of the total moose pellet groups.

5.2.2 Enclosure effect

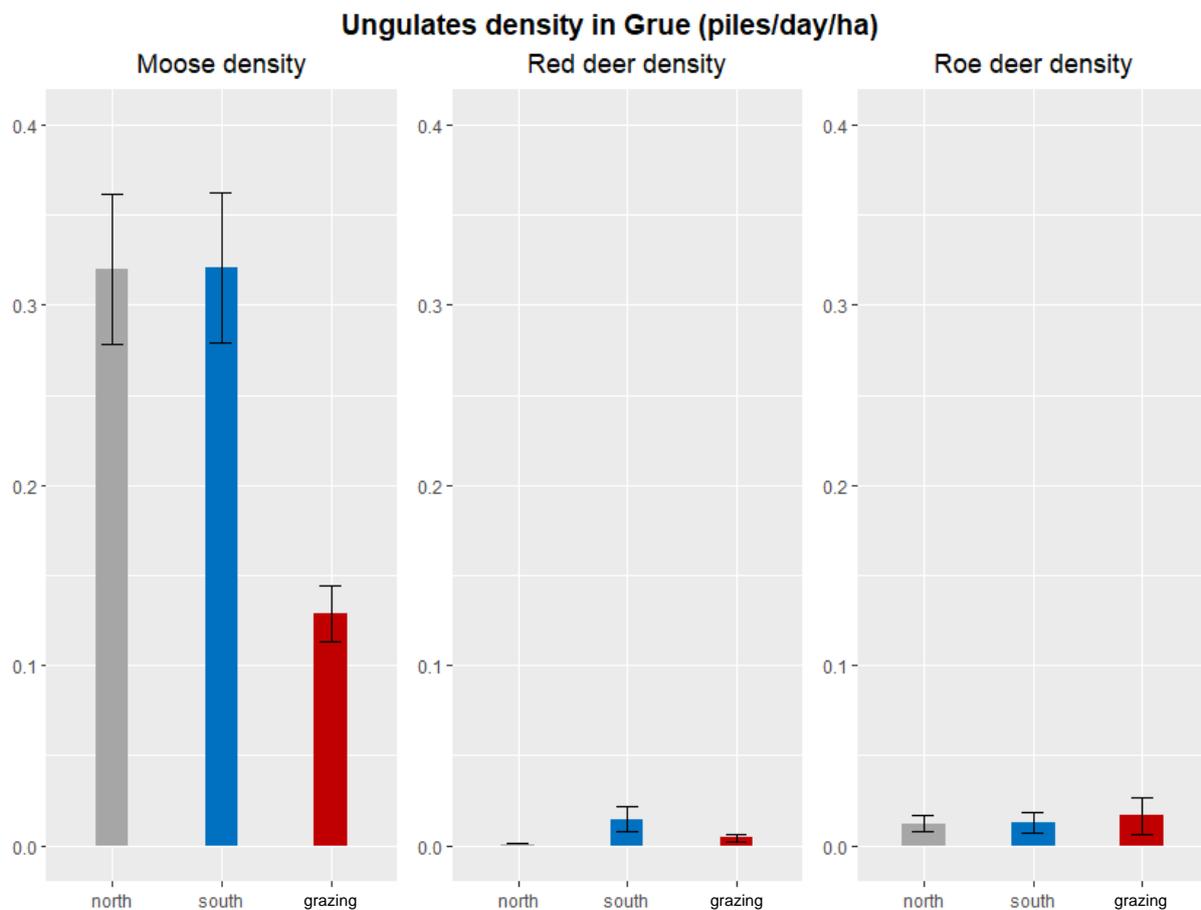


Figure 15 : Ungulates density in Grue (pellet groups/day/ha)

After performing an Kruskal-Wallis test, the variable “zone” had a significant effect on moose density with a p-value of $0.1e^{-2}$. In addition, thanks to a pairwise wilcox test, the north and south zone had a p-value of 0.76 which make their density mean similar (Figure 15). Therefore, the average density of moose pellet groups in Grue was significantly lower in the grazing area than in the control areas that have a similar between each other.

For red deer, the p-value of “zone” was significant with a value of 0.008. The pairwise wilcox test revealed with a p-value of 0.0065 that the density in the north and the south was different. The grazing area has no differences with the north and the south with respective p-value of 0.17 and 0.17 (Figure 15).

For roe deer, the chi-squared of the Kruskal-Wallis was 0.01, which is too little. Therefore, a logistic regression has been performed. The results show no significant effects of the zone in the roe deer density (Figure 15).

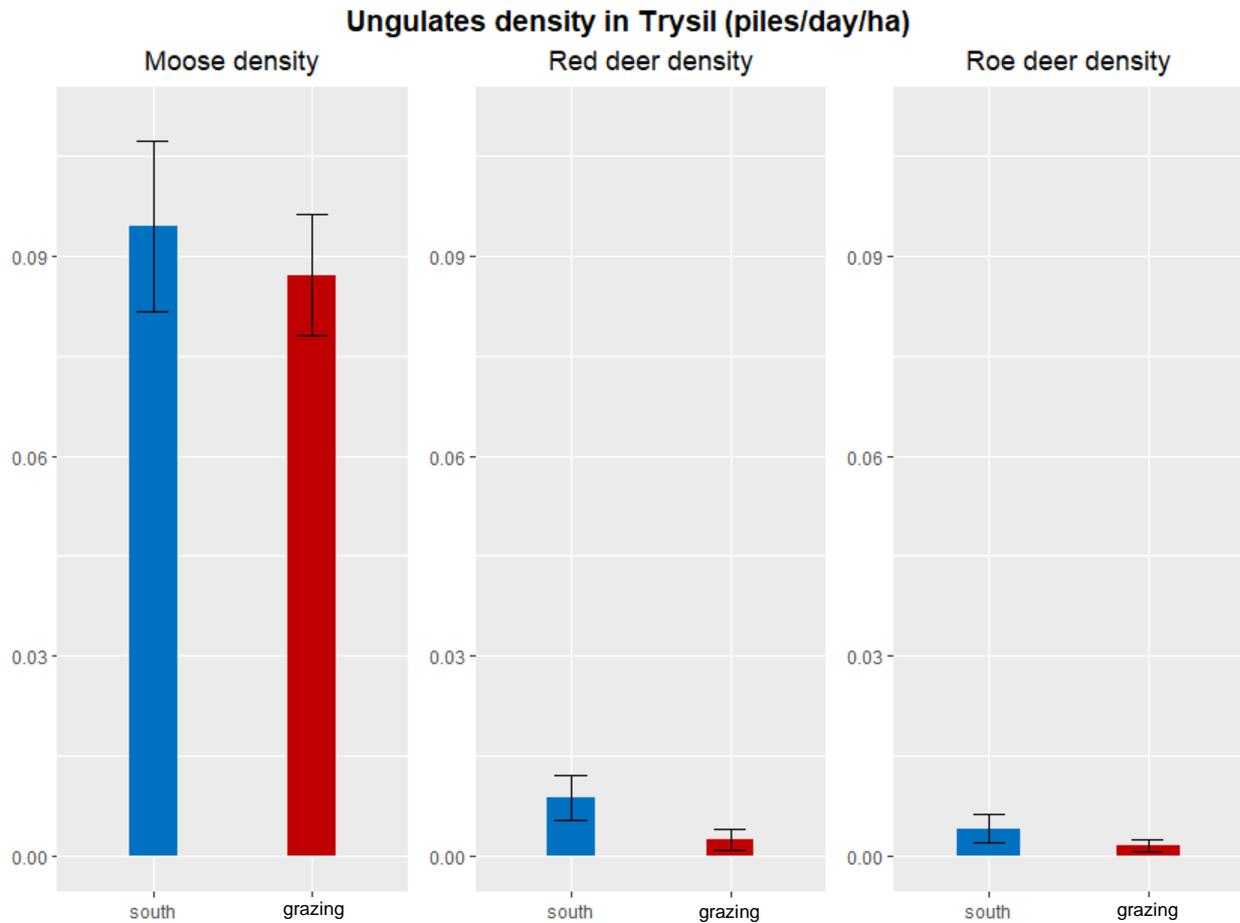


Figure 16 : Ungulate density in Trysil (pellet groups/day/ha)

For moose density in Trysil the Wilcox test gave a p-value of 0.19 which means that the density of moose pellet groups are considered as equal. For red deer the p-value was 0.03 meaning that the zone had an impact on moose density. Finally for roe deer the test shows a p-value of 0.51 which mean that we can consider the roe deer density equal in the south and the study zone.

Because of the very low number of roe and red deer pellet groups found during this campaign and the results we obtained, the next models have only been performed for the moose pellet groups.

The model 1 (Figure 17) was created with zone as an explanatory variable of pellet groups number (pellet groups number ~ zone). Because of the results of the Post-Hock test in Grue that show no difference in density between the north and the south, those zone have been merged to form only one control zone for the regression. For Grue, the result of the generalized linear model shows a significative impact of the control zone with a p-value of 4.86e-08 and an estimated coefficient of -0.91. While for Trysil, the impact is not significative with a p-value of 0.628.

All the other results from the different models are available in the following figure :

Model	Variables	Significant Variable		Grue		Trysil	
		Grue	Trysil	AIC	R ²	AIC	R ²
Model 1	1	1	-	1229	0.08	902	0.0008
Model 1.1	1-2	1-2	-	1227	0.10	904	0.001
Model 1.2	1-3	1-3	-	1221	0.12	902	0.008
Model 2	1-4-5	1-4-5	5	1213	0.14	890	0.05
Model 3	1-6	1	-	1231	0.08	904	0.001
Model 4	1-7	1	7	1230	0.09	894	0.03
Model 5	1-2-3-4-5-6-7	1-3-4-5	5	1202	0.20	893	0.07

Figure 17 : Results of tested models in each location

The best models chosen for Grue and Trysil are models 5, respectively, according to AIC and R² (Figure 17).

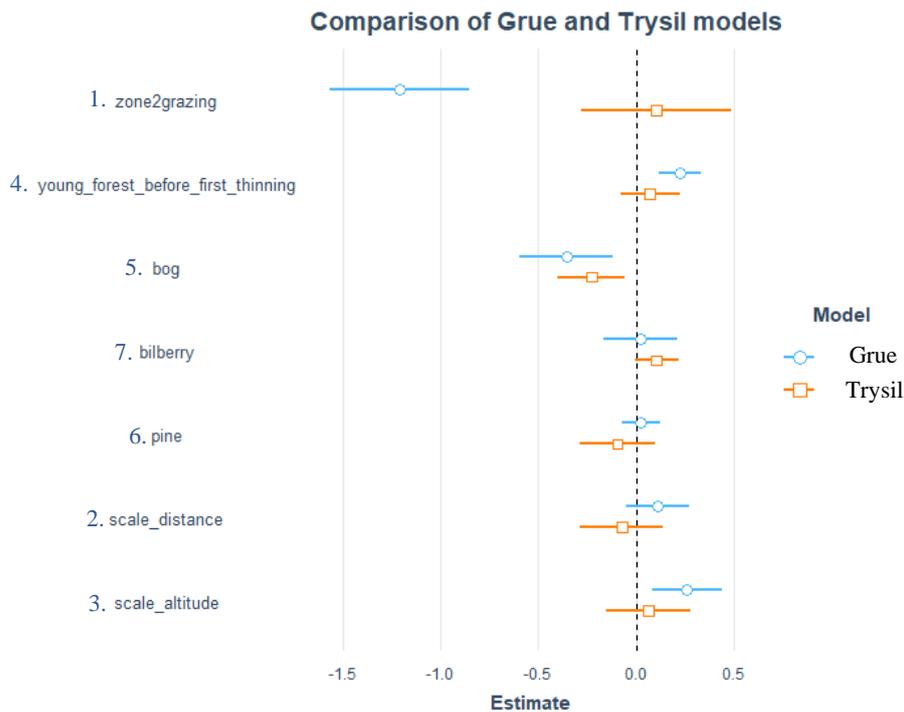


Figure 18 : Forest plot of the two chosen models

Although model 5 best describes the "number of pellet groups" variable, Trysil's model has only one significant explanatory variable, whereas Grue has four of the seven (Figure 17). The variable zone2grazing indicates that being in the grazing zone has a significant and negative impact on the presence of pellet groups with a p-value of 3.92e-16 and a coefficient of -1.21. Such an effect is not visible in Trysil (Figure 18). Moreover, for Grue the zone2grazing variable is the one that impact the most the explained variable.

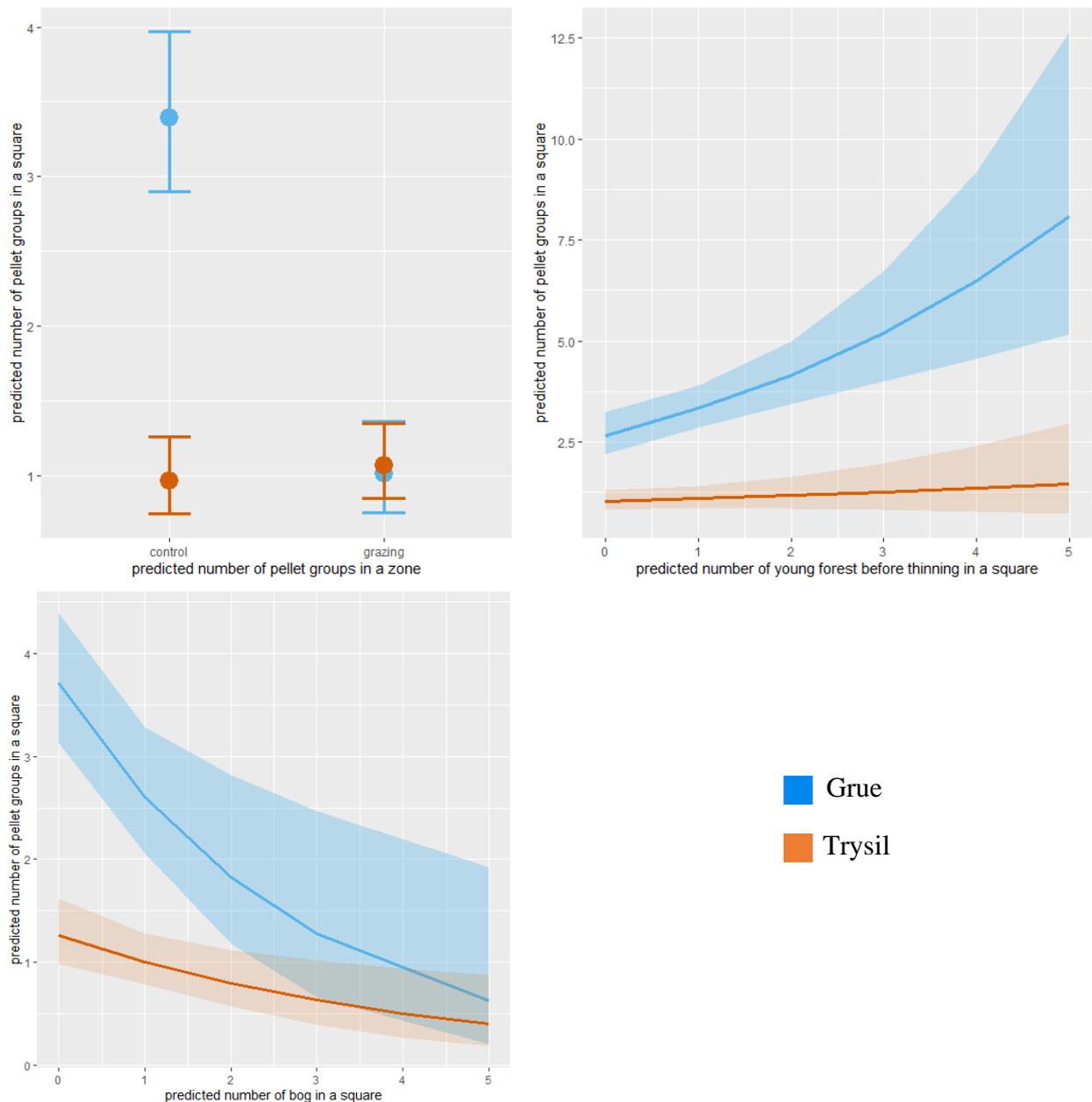


Figure 19 : Prediction plots of the models 5 using variables Zone, Bog and Young forest before first thinning

By creating prediction plots via the model, we can see how the three variables above impact the number of pellet groups that can be found in a square.

Being in the grazing zone reduces by 3 the number of pellet groups found in the case of Grue. We can also notice that Trysil has similar predictions when you are in the grazing area and that leaving the grazing area does not change the prediction.

For the two other variables we observe that the prediction curves have a greater slope in Grue than in Trysil. For the variable young forest before first thinning, the more this stand is found in the square, the more pellet groups are found.

It is the opposite for the variable bog. The more we found bog in a square, less pellet are found.

If we are looking at the the two last graph, we can also notice that Grue always have a superior number of pellet at level 0 of the predicted environment. It means that Grue, on itself had more pellet groups than Trysil.

Moreover, the prediction reach 0-1 pellet found in the square for both Trysil and Grue when the square is only bog (*Figure 19*).

6 Discussion

6.1 Fences effect

6.1.1 Grue and it's fragmented habitat

Comparisons of means and models show that there is an impact of the Grue fence. What is important to see is that this impact is greater than the environmental variables used by the moose to select its habitat (*Figure 18*). This effect is reinforced by the fact that the trends in significant variables (*Figure 18*) are consistent with the literature (H. K. Wam et Hjeljord 2010; Nikula et al. 2021). This demonstrates that the barrier is the most influential environmental factor on the presence or absence of moose among the variables we selected. Thus, the implementation of anti-carnivore barriers significantly prevents moose from entering the grazing area.

6.1.2 Forest stand, the only categorical variable that can explain habitat use

Nevertheless, our results do not allow us to study the impact of the environment beyond the forest stand category. Indeed, the variables pine, bilberry (except for Trysil), altitude (except for Grue) and distance from roads do not significantly impact density.

For the pine tree the cause can be the creation of categories representing only the majority species. In environments where several species of trees or vegetation coexisted in a balanced way, it was up to the observer to make a choice. Knowing that 11 people have joined the project, this makes it all the more possible to have an observer bias for a given environment. In the case of the description of tree species, additional categories should perhaps have been integrated. Indeed, the presence of a tree in the majority does not prevent the presence of others. In the case of pine, which is the resource favoured by moose during the winter, it would have been interesting to have information on their presence. We could have had "mixed forest of pine and spruce" or even "spruce forest with some pine". This would have allowed us to have a gradient of pine presence and thus to have a more precise model. This is potentially why young forest before first thinning is a significant variable but not pine. Through the method used, the importance of pine is poorly estimated but is potentially found through the variable describing the forest stand.

For bilberry these are two effects that may call into question the data obtained. We decided to base our estimate on which species has the most access to light. First, as for the dominant tree species, it is up to the observer to choose when the vegetation appears homogeneous. Secondly, the phenology of the bilberry and in particular the appearance of the leaves causes a bias of analysis with our method. The counting campaign starting at snow melt, the bilberries are present only in stem form. In this form their access to light is limited and mosses was therefore generally the most abundant plant species. However, our counting period extended until the appearance of leaves and the bilberries thus became dominant in the environment. This is why in Trysil we observe a change in the dominant plant species of the soil between the grazing area and the south (*Figure 12*). By the time we finish working in the grazing area, the billberies have had time to leaf out, which may explain the significance of the variable for Trysil and not Grue (*Figure 18*). However, moose also feed on bilberry stems especially during winter (H. K. Wam et Hjeljord 2010). Therefore, estimating ground vegetation by the visually abundant species

may not be the best option for detecting an effect on whether moose are present or not. However, although during winter moose consume bilberry stems, it is not clear that they select their environment for this resource. Their behaviour consists more of walking and grazing on the ground, rather than staying in one place. This behaviour could during the winter, make the ground vegetation and thus the bilberry an environmental characteristic can explain the use of their environment.

6.1.3 Moose migration causing a low Trysil moose density

Although the results tend to validate the second hypothesis, it is important to take into consideration the migration of certain moose populations. Indeed, moose can migrate from one place to another in Norway. Factors such as access to food and the amount of snow impact this phenomenon. Too much snow and too few pine trees cause them to migrate to Sweden when they are located in the Hedmark region (Zimmermann et al. 2022). In the case of our study, Grue area is known to have a continuously remaining population of moose. However, Trysil, a region with abundant snow, is an area with a very low population of moose during the winter. This is why moose density is much lower in Trysil than in Grue. This low density could be the reason why there is no difference between the inside and the outside of the barrier from a statistical point of view.

The Ideal Free Distribution theory is a theoretical way in which individuals in a population distribute themselves among several resource patches in their environment to minimize competition for resources and maximize their fitness (Fretwell 1972). Therefore, a low density of moose could induce them to take up more space and move more often between the grazing area and the outside. This would favour the validation of hypothesis 2 meaning that removing the fence during the winter is a way to reduce the fragmentation effect of it.

Hypothesis 2 can be validated by the results, but with the low density of elk in Trysil these results can be questioned.

6.2 Square method

6.2.1 Pellet group counting

The use of pellet counting to analyse how herbivores use their home range is a proven practice and provides results that are consistent with reality (Månsson, Andrén, and Sand 2011). Nevertheless, many factors can affect the quality of these results. The light conditions and in particular the amount of contrast that the sun will create makes it more or less easy to detect pellets. This effect, combined with the presence of vegetation only increases the chances of having poorly accurate results (Jung et Kukka 2016). Although our counts took place at the end of winter, by the time all the work was done the vegetation had time to come out of dormancy. Therefore, for Trysil we observe a difference in soil vegetation. The North zone was carried out first and the time to pass to the South zone, the bilberries had taken the bottom. In a similar way, Grue was composed of 20% of clear cut. Depending on the quality of the cut, many branches may limit the visibility of the dung. The quality of the environment in which the observer is working therefore determines the visibility of the pellets (Lioy et al. 2014). Added to this is the detectability of the dung itself. Although moose and red deer are species whose scat is easily detectable because it is relatively large and stacked (Lioy et al. 2014), the smaller the population, the less accurate the count will be no matter how hard you try (Alves et al. 2013). Trysil and Grue are areas with low roe deer and red deer densities, so this must have amplified the underestimation of populations, which did not allow us to perform a statistical test. In addition, the lack of difference between the inside and outside of the grazing area even for moose can also be questioned because of the low winter moose population in Trysil. It is up to the observer to adapt to overcome these problems. The use of a two-observer method is

recommended to limit the number of undetected pellet groups (Jenkins et Manly 2008; Loosen et al. 2022). Implementing a clockwise and then counter-clockwise counting methodology could therefore have the same effect as a two-observer method. Indeed, it allows to spend more time on the search area, but also to cover it in a different way and thus maximize the surface covered by the gaze.

In addition, the environment also plays a role in the way the droppings will persist over time. Pellets can be caused to deteriorate due to abiotic factors such as wind, sun, or rain, or due to biotic factors primarily related to microbial activity (Jung and Kukka 2016). Collecting pellets representing winter activity is an advantage because the cold weather limits pellet degradation and especially biotic effects. Wet areas also act in the same way however, this will make the pellets more fragile and prone to loosening. Since the way a pellet is held is a criterion for estimating age, some could be considered to be from before the winter of 2021 and therefore not be counted. Although site moisture was not a variable that was recorded, the article by authors Jung and Mukka 2016 confirms our observations. Young spruce forests are the forest stages in which it is wettest, which corresponds to the majority of Grue forests. Trysil, on the other hand, may have mostly old spruce forests, but it was a predominantly wet area. Nevertheless, the possibility to edit our forms after collection allowed us to resolve some uncertainties about the age of some scats.

The modification of the shape of the pellets was also very useful when we had problems identifying species. Depending on their diet and therefore the season, herbivores can have very varied forms of excrement. The moose in particular makes excrement in the shape of an oval pellet during the winter, and dung during the summer. Thus, during the diet transition period, it can be difficult to distinguish moose from red deer. The more animals are of the same size and moreover belong to the same taxon, the error can be relatively high (Spitzer et al. 2019). Nevertheless, the low density of red deer in the grazing area is to our advantage for this case.

6.3 Management of the barrier and benefits

6.3.1 Remove the fence in winter to reduce maintenance costs

Although these two areas have the same type of barrier, the management of it is different. Unfortunately the realization of interview with people being part of the LGA was not possible for lack of answer. The following suppositions are only made by simple visual observation and brief discussion with some locals.

Having been able to observe the barrier of Trysil once assembled, it was easy to note certain differences between the two fences (*Appendix 4*). They are composed of wooden posts between which are arranged plastic stakes, and it was not rare to see some broken in Grue. In general, the fence of Grue seemed to be in a worse state than the one of Trysil. Leaving the fence during the winter would potentially put more pressure on it because of animal crossing it. The material would be put under more strain and would degrade more quickly than in Trysil.

So although leaving the barrier in place during the winter does not cause any workload related to the dismantling and reassembling of the barrier, it is possible that it would create a potentially higher maintenance load. This could even impact the quality of the barrier and therefore not be as effective against carnivores. For example, during the count campaign in September 2022, the presence of sheep outside the enclosure was reported, potentially demonstrating that the management of the enclosure could be reviewed.

The way Trysil manages its fence is to simply lay the plastic stakes and wires on the ground, which makes it easier to put back in place. The fence is then protected by the snow cover during the winter, which prevents the animals from getting tangled up in it. It can be assumed that the

practice of removing the barrier during the winter may be a good practice for wild ungulates, but also for maintenance. It is therefore probably a practice that is also in favor of the breeders to limit the costs of maintenance and loss of livestock in fine.

6.3.2 [Moose Grazing as a Service to farmers](#)

In the types of trophic interactions between herbivores, it is important to mention the principle of facilitation. The presence of one species may facilitate the feeding of another and thus facilitate the survival of a population. A species can also transform a habitat by its presence and actions, facilitating the survival of another (Arsenault et Owen-Smith 2002).

Allowing moose access to the grazing area during the winter could facilitate the regrowth of grazing material, and thus provide sufficient food for the sheep year after year. Indeed, if sheep are the majority herbivores in the grazing area and only during the summer, a vicious circle can be set up. Sheep are considered grazers but they graze in a browser ecosystem. The vegetal resource that they will feed on is not the one that is in the majority. This resource will therefore be in competition with the bilberry, since during the summer it is the main plant species. This competition will be all the more important if the sheep weaken the survival of the plant species by eating it. For example, sheep feed on grass, but it needs light to grow. If the quantity of bilberry is too important, this species will take over the grass because it will block the access to the light. So, the presence of browsers could limit this effect by maintaining a balance between browsing and grazing materials and maintaining a balanced environment. By allowing browsers to feed in the grazing area, it would allow for a sustainable environment for this agricultural practice by avoiding depletion of the resource. Although many other factors may determine the composition of the soil vegetation, it is possible that the presence of more grass in Trysil compared to Grue can be explained by this mechanism.

6.3.3 [More space for moose, less damage to forestry](#)

As mentioned earlier, moose will primarily feed in young forests by eating pine stems. Depending on the density of the moose population, this pressure on young forests may be so great that it will affect the yield of the forest in the future (Hörnberg 2001). However, damage cannot be estimated solely by looking at moose density. Other factors such as the proportions of different forest stand types, the proportion of species within the forest stand, and the total area available for moose must be considered. Grue is an area where forestry activity is predominant, so it is possible that they will face this problem. Removing the barrier during the winter in Grue could therefore allow moose to have a larger area available, and thus potentially spread out their grazing pressure leading to a local decrease in their damage.

6.4 [The barrier effect, an ongoing study](#)

As mentioned previously, the results obtained are based on data from the winter activity of moose in each of the zones. Nevertheless, the INN has carried out a second counting campaign in September 2022 in order to know the summer activity. This will allow us to verify the impact of Grue fence, but also to see if such an effect is perceptible in Trysil when the barrier is rebuilt. Following this, it would have been interesting to repeat an analysis of the winter and summer activity in 2023 by agreeing with Grue farmers to apply the same management as Trysil to their barrier.

Thus, through these two years of data collection and this methodology, it may be possible to verify that the enclosure does have an impact on the distribution of moose in the area, and that the way the barrier is managed may limit this effect. However, it is unlikely that a second year of study will continue in this area, and it is even less likely that Grue farmers will agree to change their practices.

7 Conclusion

The results obtained validate both hypotheses. The installation of an anti-carnivore barrier to protect the sheep during their summer grazing impacts the density of moose presence. Furthermore, removing this barrier during winter would seem to avoid the fragmentation of their habitat. However, these results can be questioned for different reasons. Our methodology compared two different practices carried out in different environments. Indeed, Grue has a more intense forestry activity than Trysil, which results in forests of different structure and composition. This difference makes the moose populations not comparable either. In Grue the population tends to stay put, while in Trysil it migrates to Sweden during the winter. The way in which the data was collected also plays a role in the results obtained.

The methodology we used allows us to have a relatively accurate idea of the density of large herbivores, particularly moose. The pellet counting method is relatively simple but it requires some expertise on the part of the observer, which will subsequently impact the quality of the results obtained. The accuracy of the results depends on the observers and the quality of their work. The analysis of the environment also has some points of discussion that we must be aware of. However, the methodology applied was not intended to determine how the vegetation impacts the presence of these species. The use of the dominant species gives results consistent with what is found in the literature, which tends to confirm that it is not necessarily necessary to go deeper into the analysis of the vegetation.

In order to overcome these biases, another campaign was carried out in September 2022 in order to know the summer activity of the ungulates and then validate or not the results obtained with the winter activity.

In addition, the results of this study will allow us to raise new hypotheses about the interest of focusing on the management of these enclosures in order to have beneficial repercussions for the environment, the farmers and forest owners. While the cost of maintaining the fences will not be studied, INN's CarniForeGraze project is analyzing the impact of livestock grazing in forests. All of this research, including this one, could thus allow for the adoption of agricultural practices that are appropriate to the system in which they are embedded. Agriculture and the environment are closely linked and taking all these factors into account will lead to a sustainable territory allowing the conservation of practices anchored in the agriculture of Norway.

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Appendix

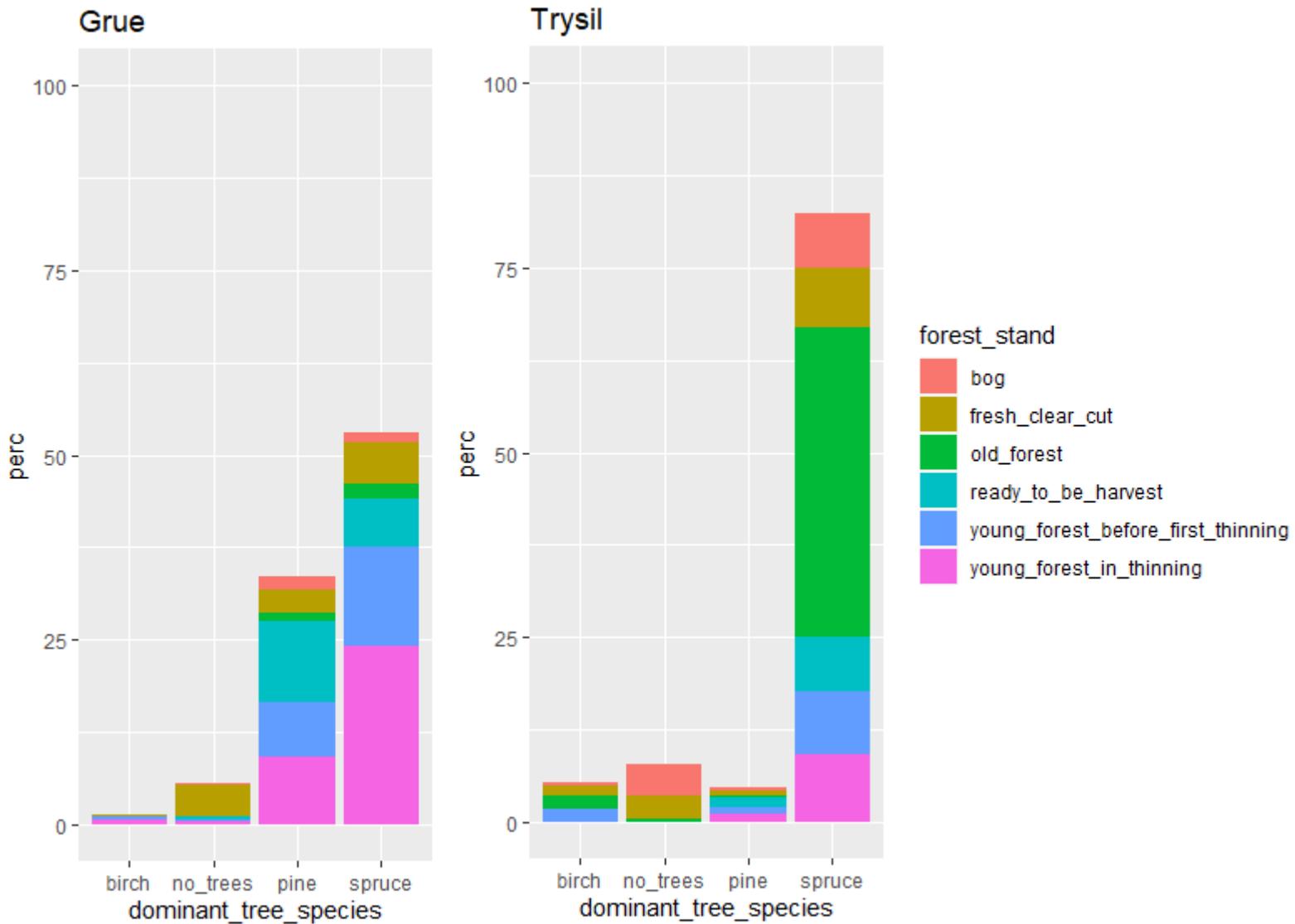
Appendix 1 : Data frame composition and variable characteristics

'data.frame': 308 obs. of 40 variables:

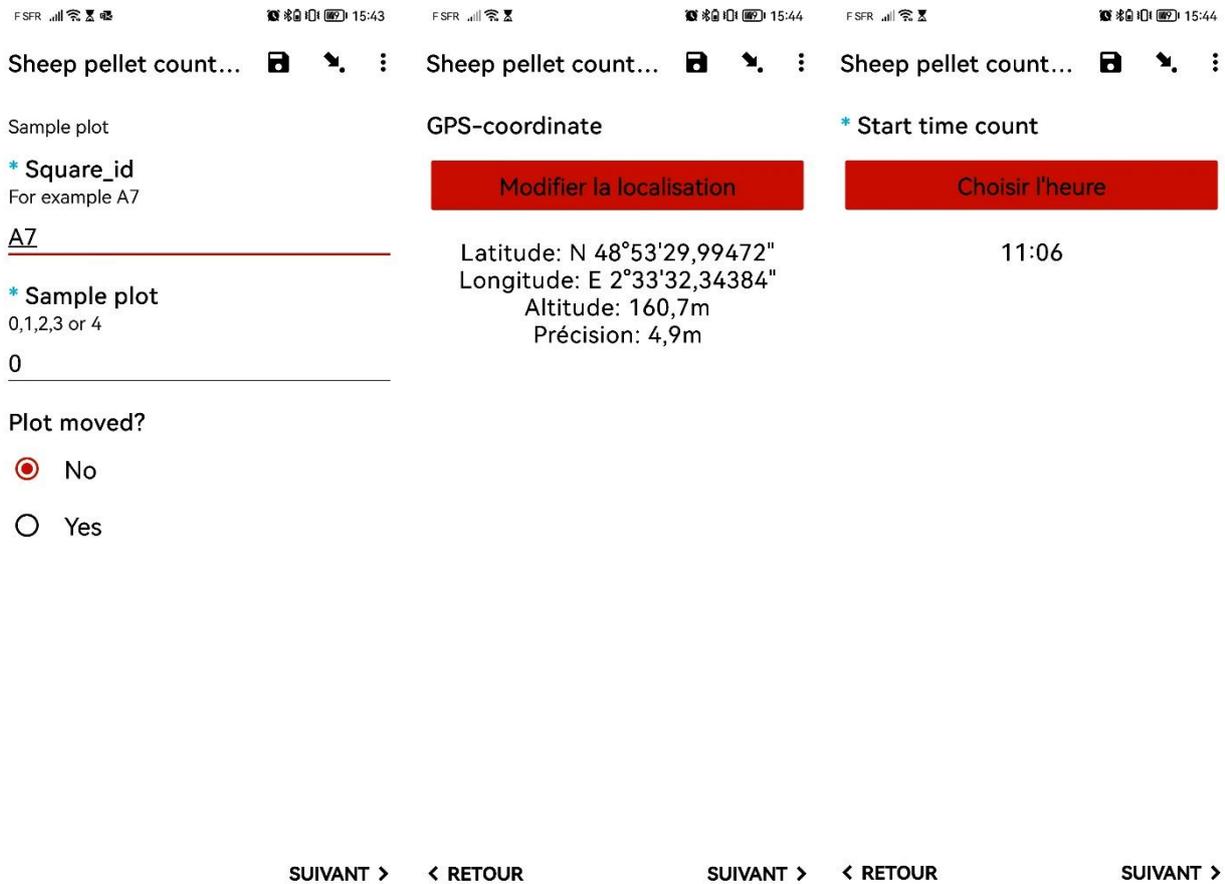
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$ square_id : chr "B12" "B13" "B14" "B15" ...
$ zone : chr "study" "study" "study" "study" ...
$ time_period : num 244 246 246 246 246 ...
$ latitude : num 61.5 61.5 61.5 61.5 61.5 ...
$ longitude : num 12.2 12.2 12.2 12.2 12.2 ...
$ altitude : num 705 708 734 767 760 ...
$ moose_density : num 0 0 0.0813 0 0.1625 ...
$ total_moose : num 0 0 1 0 2 3 1 5 1 0 ...
$ red_deer_density : num 0 0 0 0 0 0 0 0 0 ...
$ total_reddeer : num 0 0 0 0 0 0 0 0 0 ...
$ roe_deer_density : num 0 0 0 0 0 0 0 0 0 ...
$ total_roedeer : num 0 0 0 0 0 0 0 0 0 ...
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$ capercaillie : chr "no" "no" "no" "yes" ...
$ black_grouse : chr "yes" "no" "no" "no" ...
$ other_grouse : chr "no" "no" "no" "no" ...
$ forest_stand : chr "bog" "young_forest_in_thinning"...
$ fresh_clear_cut : num 0 0 0 3 0 2 0 0 0 ...
$ young_forest_before_first_thinning: num 0 0 0 2 1 0 0 0 0 ...
$ young_forest_in_thinning : num 0 4 4 3 0 3 1 0 0 3 ...
$ ready_to_be_harvest : num 2 0 1 0 0 0 0 4 0 2 ...
$ old_forest : num 0 0 0 2 0 0 0 0 0 0 ...
$ bog : num 3 0 0 0 0 0 2 0 5 0 ...
$ other : num 0 1 0 0 0 1 0 1 0 0 ...
$ dominant_tree_species : chr "spruce" "spruce" "spruce" "spruce" ...
$ pine : num 0 0 0 1 2 0 1 0 0 0 ...
$ spruce : num 3 4 5 4 2 4 2 4 0 5 ...
$ birch : num 0 0 0 0 1 0 0 0 0 0 ...
$ no_trees : num 2 1 0 0 0 1 2 0 5 0 ...
$ dominant_ground_vegetation : chr "mosses" "bilberry" "bilberry" "bilberry" ...
$ bilberry : num 0 3 3 5 4 3 1 4 0 0 ...
$ cowberry : num 0 0 0 0 0 0 0 0 0 0 ...
$ crowberry : num 0 0 0 0 1 0 1 0 0 2 ...
$ grasses_and_herbs : num 1 0 0 0 0 0 0 0 0 0 ...
$ lichens : num 0 0 0 0 0 0 0 0 0 0 ...
$ mosses : num 4 1 1 0 0 2 3 1 5 3 ...
$ stones_bare_soil : num 0 0 0 0 0 0 0 0 0 0 ...
$ other_heather_species : num 0 0 0 0 0 0 0 0 0 0 ...
$ distance_to_roads : num 294.1 49.1 212.1 291.2 131.3 ...
```

Appendix 2 : Percentage of dominant tree species in each habitat type

Number of dominant tree species in each habitat type



Appendix 3 : Screenshot of the Koboform used during fieldwork



First round (clockwise): Number of summer piles

*** Roe deer piles**

Search the inner circle only for roe deer (10 m2)

1

Presence of other species in inner circle

Only in the 10 m2 circle!

- Hare
- Black grouse
- Capercaillie
- Other/undetermined grouse
- Other species...

*** Moose piles**

Search the entire 100 m2 circle. Only from after last leaf fall.

2

*** Red deer piles**

Search the entire 100 m2 circle. Only from after last leaf fall.

0

< RETOUR

SUIVANT >

*** Other species in the outer circle**
Don't search actively for other species, just if you see feces by chance.

- Hare
- No additional feces detected
- Capercaillie
- Black grouse
- Other/undetermined grouse
- Other...

< RETOUR

SUIVANT >

Second round (counter-clockwise): ADDITIONAL piles

*** Roe deer piles**

Search the inner circle only for roe deer (10 m2)

0

Presence of other species in inner circle additional presence

Only in the 10 m2 circle!

- Hare
- Black grouse
- Capercaillie
- Other/undetermined grouse
- Other species...

*** Moose piles**

Search the entire 100 m2 circle. Only from after last leaf fall.

1

*** Red deer piles**

Search the entire 100 m2 circle. Only from after last leaf fall.

0

< RETOUR

SUIVANT >

Forest stand age or other habitat type

Age of the forest stand where the plot (or most of the plot) is situated.

- 1 (fresh clearcut, ready for planting and re-growth)
- 2 (young forest before first thinning, trees up to 10-12 m)
- 3 (young forest in thinning stage)
- 4 (forest ready to be harvested)
- 5 (old-growth forest)
- Bog
- Other...

< RETOUR

SUIVANT >

*** End time count**

Choisir l'heure

11:14

< RETOUR

SUIVANT >

Dominant tree species

On the forest stand where the plot (or most of it) belongs to

- Pine
- Spruce
- Birch
- Willow
- Other deciduous species
- No trees

< RETOUR

SUIVANT >

Sheep pellet count...

Dominant ground vegetation

Within the 100 m² circle. Choose the type with the highest coverage when looking from above. Rough, quick estimate.

- Lichens
- Mosses
- Grasses and herbs
- Bilberry (blue berries)
- Crowberry (black berries, needle leaves)
- Cowberry (red berries, leathery leaves)
- Other heather species
- Stones, bare soil

< RETOUR

SUIVANT >

Sheep pellet count...

Pellet removal

*** All piles removed?**

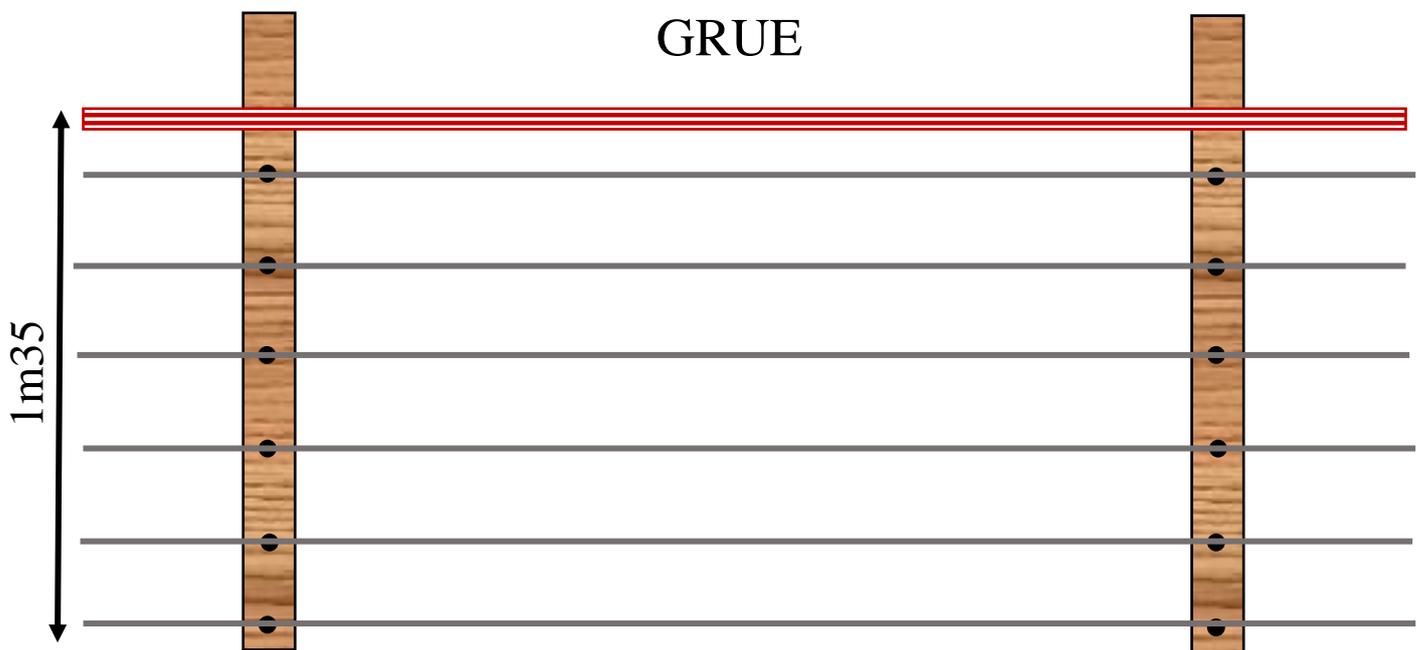
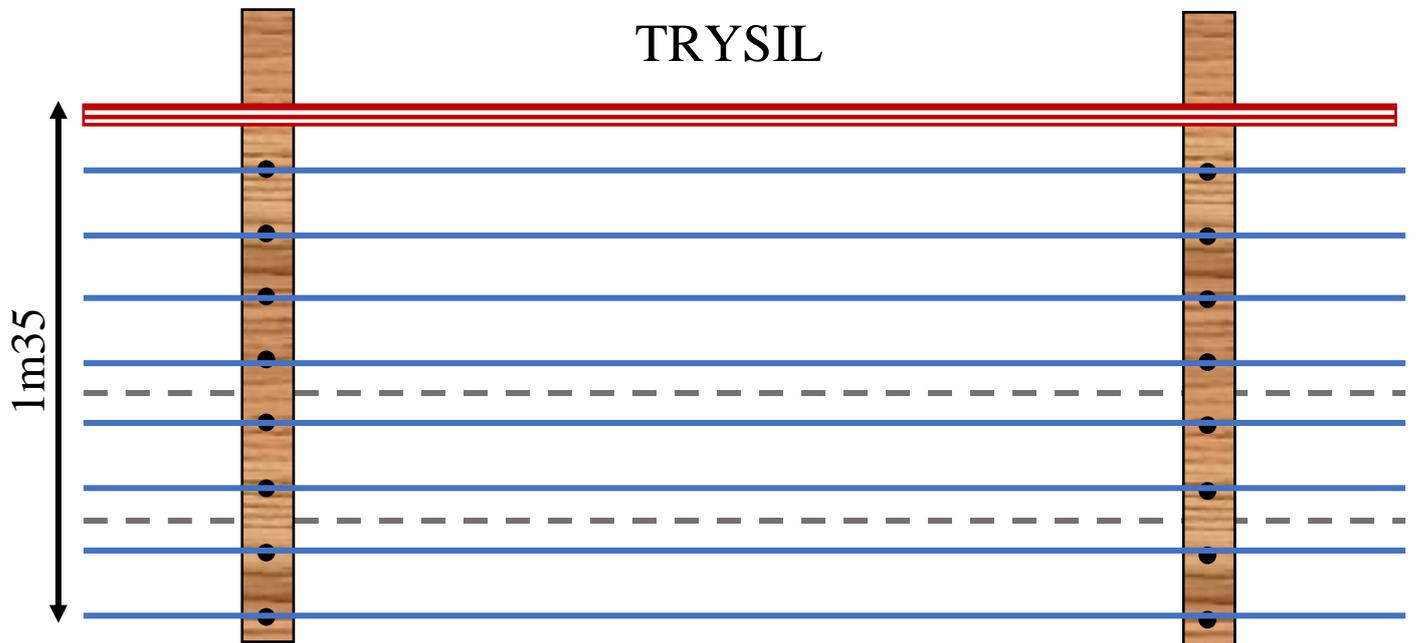
Throw all pellets out of the plot. Answer yes also if there were no piles.

- OK. Continuer.

< RETOUR

SUIVANT >

Appendix 4 : Carnivore proof fences in Trysil and Grue



 wooden pole

 metal wire

 isolator

 metal wire on the other side of the pole

 electrified strip

 electrified metal wire



LISSILLOUR Pierre, 2022, Carnivore proof fences : A fragmentation factor for wild ungulate, 41 pages, thesis of end of studies, defended on September 29, 2022 at the Campus agronomique de VetAgro Sup, Lempdes.

HOST STRUCTURE AND ASSOCIATED INSTITUTIONS:

- Inland Norway University of applied sciences

SUPERVISORS :

- Supervisor : ZIMMERMANN Barbara (INN)
- Pedagogical tutor : BRUNSCHWIG Gilles

OPTION : Agriculture, Environment, Health, Territory

ABSTRACT

Norway is known to host 4 large carnivore species that conflict with the country's agricultural practices. The return of the wolves, bears, lynx and wolverines after their near extinction in the 19th century, has forced farmers to adapt and put their sheep in fenced in forest areas during the summer grazing period. Hedmark represents the Norwegian region where the protection areas of these 4 carnivores overlap which make it a place of risk for livestock. Trysil and Grue are two areas in this region that have built anti-carnivore barriers. Nevertheless, they manage their fences differently. In Trysil the barrier is dismantled during the winter while in Grue it is left. The Inland Norway University of Applied Sciences wanted to investigate if fences protecting sheep in forests against potential carnivores are factors of habitat fragmentation for wild ungulates and if such an impact exists, does the way the fence is managed mitigate this factor. A pellet count campaign has been conducted from May 2022 to June 2022 to determine the winter activity of moose, red deer and deer in each area. The results show that the fence does create a fragmentation of the moose habitat, and that the absence of the fence during the winter limits this effect. Nevertheless, in addition to being beneficial to wildlife, removing the barrier during the winter may also serve farmers by limiting repair damage and promoting an environment conducive to grass regrowth in the grazing area. It could also reduce the impact moose have and improve young tree growth and forest productivity. Fence management is therefore not only a mean to have environmental good practice but also favor all activities that take place in the forest.

Key words : moose density-pellet counting-carnivore proof fence

RESUMÉ

La Norvège est connue pour abriter 4 grands carnivores qui entrent en conflit avec les pratiques agricoles du pays. Le retour du loup, de l'ours, du lynx et du carcajou après leur quasi-extinction au 19ème siècle, a obligé les agriculteurs à s'adapter et à placer leurs moutons dans des zones clôturées pendant la période de pâturage estival en forêt. Hedmark représente la région norvégienne où les zones de protection de ces 4 carnivores se chevauchent et en font un lieu à risque pour le bétail. Trysil et Grue sont deux zones de cette région qui ont construit des barrières anti-carnivores. Néanmoins leur gestion de celle-ci est différente car à Trysil la barrière est démantelée pendant l'hiver alors qu'à Grue elle est laissée en place. L'Université des sciences appliquées d'Inland en Norvège a décidé d'étudier si les clôtures mises en place pour protéger les moutons en forêt contre les carnivores sont des facteurs de fragmentation de l'habitat des ongulés sauvages et si un tel impact existe, est-ce que la façon dont la clôture est gérée peut atténuer ce facteur. Une campagne de comptage de pile fécale a été menée de mai 2022 à juin 2022 pour déterminer l'activité hivernale des élan, des cerfs et des chevreuils dans chaque zone. Les résultats montrent que la clôture crée bien une fragmentation de l'habitat de l'élan, et que l'absence de la clôture pendant l'hiver limite cet effet. Néanmoins, en plus d'être bénéfique pour la faune, le démantèlement de la barrière pendant l'hiver peut également servir aux agriculteurs en limitant les dommages de réparation et en favorisant un environnement propice à la repousse de l'herbe dans la zone de pâturage. Cela pourrait également réduire l'impact que les élan ont sur la croissance des jeunes arbres et donc sur la productivité de la forêt. La gestion des clôtures est donc non seulement un moyen d'avoir de bonnes pratiques environnementales mais aussi de favoriser toutes les activités qui ont lieu en forêt.

Mots clés : densité d'élan - comptage fécaux - clôture anti-carnivores.