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Master's thesis

Evaluating potential drivers of four different types of moose browsing damage in a cross-border context

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POTENTIAL DRIVERS OF BROWSING DAMAGE IN A CROSS-BORDER CONTEXT

ABSTRACT: Moose (*Alces alces*) in Scandinavia rely on commercially valuable Scots pine (*Pinus sylvestris*) as a winter food source. Browsing impacts to forest resources are labeled as "damage" and have become especially important along the border between Norway and Sweden, where a semi-migratory moose population moves seasonally between two management regimes. As part of the EU-funded GRENSEVILT project, we studied multiple factors thought to drive browsing damages within a single sub-population in a cross-border context. We combined elements of two national methods of assessing browsing damage: Solbraa (Norwegian) and Äbin (Swedish). We analyzed four damage indicators (stem breakage, bark browsing, browsing pressure, and number of winter-browsed top shoots) by grouping over 20 predictor variables into three categories, using data collected on 3,033 individual pine trees. GLMM model variable selection was completed using AIC. Covariates that measured severity of prior damage (such as cumulative impacts on plant architecture) were included in the top models for all four indicators. Notably, the covariates for pine density and snow depth, factors previously found to be important in predicting browsing damage, were not present in any of the top models. GAM landscape models revealed that distributions of the four damage types are quite different – with bark browsing illustrating an isolated "hotspot" and browsing pressure showing more widespread prevalence. There is some evidence to suggest that different damage types represent a natural progression of moose foraging, with stem breakage and bark browsing signaling more severe damage and potential over-use with time.

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Key Words: *Alces alces*, browsing, damage, forestry, habitat management, moose, *Pinus sylvestris*, Scandinavia, Scots pine

I now suspect that just as a deer herd lives in mortal fear of its wolves, so does a mountain live in mortal fear of its deer." ~Aldo Leopold, A Sand County Almanac (1949)

Moose (*Alces alces*) are important consumers in the boreal forests throughout their circumpolar distribution. As the largest member of the deer family (*Cervidae*), moose require a proportionally large absolute volume of forage to sustain themselves. Although metabolism can shift seasonally, and differs by sex, age, and reproductive status (Regelin *et al.* 1985, Schwartz 2007) estimates suggest that the average Scandinavian moose needs to consume a dozen kilograms of (dry) forage per day (Fremming 1999, Sæther *et al.* 1992, Schwartz *et al.* 1988) to meet its basic energetic needs. During the winter, a critical time when many other sources of forage are unavailable, moose in Norway and Sweden rely heavily on the relatively palatable conifer Scots pine (*Pinus sylvestris*). This is in contrast to North American moose, which derive 75-91% of both their winter and summer diet from deciduous species in a single genus (*Salix* or willow; Shipley 2010). Although Norway spruce (*Picea* a*bies*) is co-dominant in the Scandinavian forest system, this species is not preferred by moose to the same extent as Scots pine (Lodin *et al.* 2017, Mansson *et al.* 2007).

Browsing has ecological impacts at multiple scales, from altering individual plant architectures (Yovovich et al., 2021) to changing landscape-level ecological function by interrupting successional trajectories (Kolstad et al., 2018; Miquelle & Van Ballenberghe, 1989), affecting nutrient cycling (Kielland & Bryant, 1998; Pastor et al., 1993), soil fertility (Pastor et al., 1993), and resulting in cascading effects on songbird communities (Chollet & Martin, 2013; Mathisen & Skarpe, 2011). Moose browsing has even been shown to change forestry management practices (Felton et al., 2020), is used as a measurement of habitat health (Burkholder et al., 2017) and as a decision tool for both wildlife managers controlling populations (Bower et al., 2014) and private forest owners (Wam & Hofstad, 2007).

Moose browsing has been extensively studied in Scandinavia and is dependent on a number of factors, including forage availability (Bergqvist *et al.* 2018, Beest *et al.* 2010), nutritive quality (Schrempp *et al.* 2019), alternate forage availability and preference (Månsson *et al.* 2007, Wam & Hjeljord 2010), and presence of previous browsing on individual trees (Mathisen *et al.* 2017). At the forest stand level, factors include the density of cervid conspecifics (Pfeffer *et al.* 2021), interspecific cervid competition (Spitzer *et al.* 2021), and winter severity or snow depth (Gicquel *et al.* 2020). At an even larger scale, the nutritional landscape for moose is also related to disturbance history such as timber harvest and forest fires (Ericsson et al. 2001, Fisher & Wilkinson 2005), and forestry road networks (Loosen *et al.* 2021). Recently, Pfeffer *et al.* (2020) found on a national scale, factors such as winter severity, pine density, and competition from other cervids impact moose browsing damage on a latitudinal gradient in Sweden.

Outside of their role as consumers in the ecological system, moose also have profound impacts on silviculture. Plant architecture is a significant determiner of individual life history (Archibald & Bond 2003) and repeated cervid browsing favors lateral growth (hedge-type growth form) over vertical growth (Jager & Pastor 2010). Since height-gain is crucial for timber production, repeated or severe cervid browsing that hinders the normal vertical growth of an individual is labeled as "damage". Potential wood quality reductions and economic losses caused by cervid browsing were estimated between 40-80 million (USD) in Norway, after accounting for the long-term revenue losses on slow growing pine stands (Storaas *et al.* 2001). To make matters worse, rotational timberlands that are intensively managed have been shown to experience more damage and are more susceptible to damage, since management practices are designed to increase tree productivity (Kline *et al.* 2018).

The intersections between the ecological, silvicultural, and human dimensions of browsing damage is only further complicated when viewed through a geopolitical lens. Norway and Sweden "share" a semi-migratory moose population, with parts of their seasonal home range in both countries (Bramorska 2020). The moose in this area travel only 20 km (~12.5 miles), but the scale of silvicultural management also changes over this invisible border; Norway is reliant primarily on small, local forest owners to determine the harvest regime, whereas Sweden has state-owned and commercial companies that harvest larger areas. Browsing damages are defined, quantified, and managed across this border using different methods, indicators, thresholds, and languages (Table 1, Sveum 2022). To the authors knowledge, no studies have directly compared different types of damage or looked at browsing damages in two different countries simultaneously.

To collect a consistent dataset across this border, we created a novel, hybrid protocol between the Swedish (Äbin; Kalén *et al.* 2018, SFA 2018 https://www.skogsstyrelsen.se/abin) and Norwegian (Solbraa; Skogkurs 2017) methods for quantifying and measuring browsing damage. Solbraa defines damage severity by browsing pressure, whereas Äbin uses the percentage of fresh damage, especially of the top-shoot (the primary meristematic tissue responsible for vertical growth). Both methods do not collect data about the primary variable of interest in the other, making comparing these two datasets difficult. Both methods do collect information about other types of damage, namely: bark browsing and stem breakage. Solbraa also collects information about the accumulated impacts of prior damage to the overall growth form of the tree. Efforts to harmonize methods remain an important avenue for incorporating historic data and creating consistent cross-border management moving forward (Sveum 2022).

Our analysis had two primary objectives:

A) to identify the most important covariates for predicting the four types of browsing damage (bark browsing, stem breakage, top-shoot browsing, and browsing pressure) and to examine which, if any, covariates were shared by each type of damage indicator; and

B) to use the top predictive models to map the occurrence of different damage types in our study area and look for similarities and differences in patterns and concentrations.

Using data from field surveys collected in May and June of 2021, and environmental data available for the winter of 2020-2021, we used numerous potential drivers of browsing damage for our analysis at a variety of spatial scales (tree-, plot-, and stand-level). We grouped variables into three main categories:

stand characteristics like tree density and soil productivity, environmental variables like snow depth and road density, and variables that quantified other types of damage. Our predictions, based on a body of prior knowledge, were as follows:

1) **Stand Characteristics:** Pine density, as a proxy for forage availability, (Månsson, *et al.* 2007, Pfeffer *et al.* 2021) would be included as a top covariate in the winter top-shoot browsing model, density of deciduous species would be included in the browsing pressure model (Danell *et al.* 1991, Wallgren *et al.* 2013);
2) **Environmental Variables:** Snow depth, which can prevent access to the preferred field vegetation layer (Gicquel *et al.* 2020, Månsson 2009) would be included as a top covariate in the browsing pressure model
3) **Other Damage Variables:** Measures of accumulated damage, as a proxy for degree of re-browsing, (Mathisen *et al.* 2017, Wallgren *et al*. 2013, Yovovich *et al*. 2021) would be returned as a top covariates for browsing pressure, bark browsing, and winter top-shoot browsing.
4) **Shared Covariates:** We predicted that all four damage types would be identical in the covariates selected in each category. Additionally, we predicted that the global model, with variables from all three categories, would be selected as the top model for each.
5) **Damage Distribution:** Damage types would be concentrated in hotspots, especially in areas where moose are known to congregate in the winter, such as along the border in the southcentral and southeast part of our study area (Bramorska 2020, Sand *et al.* 2022).

STUDY AREA

The GRENSEVILT study area is approximately 3500 km^2 and located in northern Finnskogen with two-thirds of the area in Innlandet county in Norway, and one-third in Värmland county, Sweden (Fig. 1). This area is largely production coniferous forests of Norway spruce and Scots pine (~80%), interspersed with small inland lakes and bogs (Norway - SR16 Dataset geonorge.no; Sweden - GSD dataset 1:50,000). Birch is the dominant deciduous tree (*Betula pubescens* and *Betula pendula*), followed by willow (*Salix* spp), rowan (*Sorbus acuparia*), aspen (*Populus tremula*), and alder (*Alnus glutinosa*). Understory vegetation is dominated by blueberry/bilberry (*Vaccinium myrtillus*), lingonberry (*Vaccinium vitis-idaea*), and heather (*Calluna vulgaris*) in forested areas, with *Sphagnum* and lichen species (*Cladonia*) in low lying bogs and more exposed ridges respectively. An estimated one-seventh of the total forest area has been harvested in the last 20 years (Hansen *et al.* 2013), following standard pre-commercial thinning and clear-cut practices. Wind power development in the north central part of the study area is ongoing.

Average snow depth between mid-October 2020 and mid-May 2021 was estimated at 11.9$\pm$8.2 cm and available on a 1x1 km grid for the study area via the seNorge snow model (Saloranta 2012). The northern third of the study area received much more snow than the south (Fig. 1). We included solar irradiance as an estimate of light availability and estimated this covariate at a 1x1 km scale also. It had a normally distributed mean of 2.23$\pm$0.42 kWh/m^2 estimated for January 1, 2021 (EU DEM v1.1 from Copernicus; 25-m pixel size).

The N50 (Norway categories R,F,K,P; www.kartverket.no) and the Allmäna og Enskilda vägar dataset (Sweden 1:100,000) datasets were used to estimate road density in a 1x1 km grid using ArcGIS (CESRI 2011, Release 10). Slope and aspect were derived from a digital elevation model (EU DEM v1.1) and averaged in a 250x250 m grid. Elevation was standardized to represent a positive or negative difference from regional mean height above sea level using a polynomial trend surface. This distinction was intended to give a better indication about whether the plot was in a valley or on a ridge, as opposed to absolute altitude. Aspect was categorized into the four primary cardinal directions.

METHODS

Study Design

Our locations utilized an existing study design for annual cervid pellet counts (Putman 1984, Spitzer *et al.* 2019), which are taken after snowmelt and before spring green-up (Persson 2003). Browsing surveys should also be done at this time, before summer growth partially compensates for and obscures damage sustained by the tree during the previous winter (Skogkurs 2017). Eligible stands within 500 m of a pre-existing pellet count point were prioritized for sampling. The 1x1 km buffers or "squares" are evenly spaced throughout the study area (Fig. 1). Both the Norwegian and Swedish methods agree about which types of stands are eligible to be assessed for damage: young forest stands of predominantly Scots pine, with an average height between 0.5 and 3.5-4.0 m (Sveum 2022). Our hybrid method further defined "predominantly Scots pine" as ≥10% of total conifer stems.

Although tree species and timber volume are available in publicly available mapping and remote sensing products, these datasets often lack information about canopy height and vice versa (Hill *et al*. 2018, Koch 2010, White *et al*. 2016). As such, we conducted an image classification analysis to identify eligible stands within sampling squares. We used the Global Forest Change Dataset, or Hansen dataset, (from Global Forest Watch, 25-m pixel size; Hansen *et al*. 2013), which documents forested areas that have been logged since 2000. Ground-truthing preliminary results indicated stands harvested 10 to 15 years ago (between 2005 and 2011) were within the target height window. The SR16 dataset was used as an input to generate a spectral band signature for predominant species within the stand (i.e., pine, spruce, or mixed), which was then used to estimate the maximum likelihood estimate for image classification. An 80x80 m grid (taken from Äbin sampling design; Kalén *et al*. 2018) in each square identified potential survey plots, up to a maximum of 15. In total, 1162 plots were selected, 725 in Norway and 437 in Sweden, in roughly half of our sampling squares (172/313).

Field Surveys

Plots measured 3.5-m in radius for a total area of 38.5 m^2, again following Äbin (Kalén *et al*. 2018). If a potential survey plot met our eligibility criteria, we counted the total number of stems for seven common tree species: Scots pine, Norway spruce, silver birch, downy birch, rowan, aspen, and willow species. We then measured the height for up to 10 stems closest to the plot center and evaluated damage on (up to) 10 pines, using distance from center to avoid observers bias towards selecting pines with the most damage. Fresh damage was defined by the following criteria:

1) Bark Browsing: the main stem (trunk) has experienced bark browsing over more than 25% of its circumference during the past winter; or
2) Stem Breakage: the main stem (trunk) has been completely or partially broken and splintered during the past winter; or
3) Top-Shoot Browse: the apical shoot (hereafter top-shoot) responsible for vertical gain has been browsed during the past winter; or
4) Browsing Pressure: the total number of freshly browsed and unbrowsed shoots accessible between 0.5 and 3.5 m were counted and expressed as a percentage of browsed to total shoots available.

Instances of previous damage (earlier than the past winter) were also recorded for bark browsing, stem breakage, and top shoot browsing. The top shoot was aged following Äbin criteria (Kalén *et al*. 2018) to the following categories: '*Winter damage'*, '*Summer damage'*, '*Both winter and summer damage'*, (within the past year) or '*Older' damage'* (> 1 year). We expanded the original Solbraa methodology (Skogkurs 2017) for categorizing accumulated damage with the following definitions: '*Undamaged*', '*Ligh*t' (lateral browse only, either fresh or old), '*Moderate*' (top shoot damage, either fresh or old, with or without lateral shoot browse), '*Intense*' (strongly altered growth form, such as the presence of multiple main stems), '*Destroyed*' (tree is standing but dead or dying, extremely limited growth), or '*Other*' (rodent browse, hare browsing, or disease impacts to normal growth pattern). To help calibrate individual preference between '*Moderate*' and '*Intense*' groups, and age the top-shoot correctly and consistently, teams frequently met in the field to discuss observations. Due to COVID-19 restrictions this was not possible to complete in-person between field teams in different countries.

Accumulated damage and season of top-shoot browse variables were converted into an average weighted index score at the plot level. We thought this metric better quantified effects of otherwise categorical variables in the immediate vicinity of each tree, with more severe damage categories receiving higher weights. Which categories received which weights is outlined in Table 2. Accumulated damage categories were reduced in the final statistical analysis to '*Undamaged*' (Undamaged, Other; n = 1132), '*Low*' (Light, Moderate; n = 1643) and '*High*' (Intense, Destroyed; n = 258).

The primary field vegetation layer was converted to an estimate of soil productivity measurement as per the Äbin methods specified in Table *2,* page 6. Grass was considered the most productive ('*Good*'), followed by blueberry ('*Moderate*'), lingonberry or heather ('*Poor*') and lastly lichen, moss, or bog ('*Very Poor'*). An in-depth comparison of the Äbin, Solbraa, and our hybrid method is discussed in further detail in Sveum (2022). A full list of all 22 covariates is provided in Table 2.

Statistical Modeling

To explore potential drivers of different types of browsing damage, we modeled each of the four different types of browsing damage (response variables) as a function of several explanatory variables using binomial regression with generalized linear mixed-effect models (GLMMs). Once important covariates were identified, we used these results to refit non-linear models to ease spatial predictions and further understand non-linear relationships with generalized additive models (GAMs).

All statistical analyses were completed using Program R version 4.1.0 (R Core Team 2021) using the 'mgcv' (Wood 2011) and 'lme4' packages (Bates *et al*. 2015) and the ggplot2 package as the primary visualization tool (Wickham 2016). All continuous covariates were scaled and centered on their z-score prior to analyses, to account for different measurement units (Borcard *et al*. 2018). All variables were also evaluated for their predictive power score (PPS) prior to analysis to identify multicollinearity (van der Laken 2021).

Spatial autocorrelation is scale-specific and has been found to be strong between plots within stands (Wallgren *et al.* 2013). Although we did not group plots into stands for this analysis, we incorporated dependency among observations between trees within the same plot (Plot) and plots within the same square (SquareID), by utilizing a nested random error structure. Random error terms for "Country" or "Field

Technician" in models did not lower AIC over sampling design. For the bark browsing and winter top-shoot models, we used a simplified random error term (1|SquareID) to avoid singularity (Bates *et al*. 2015).

We fit models to test our predictions in multiple stages. First, due to the large number of potential drivers, we group covariates into three categories: stand, environmental, and damage information (Table 2). Due to low sample size in the stem breakage and bark browsing models, we limited the number of covariates in each category to three terms (including interactions). To be consistent, this limitation was also applied to the browsing pressure and winter top shoot browsing models.

Next, we modeled all simple combinations of terms within these categories and selected the best fitting combinations using Akaike's Information Criteria (AIC). Covariates that were returned most often in the top model set (ΔAIC < 2) were then tested for possible interactions. This process does not favor certain covariates initially, but multiple top models were often selected based on the above criteria. In that case, we favored models that included our predicted covariates of interest.

Absence of correlated covariates was again verified by checking correlation values >0.6. Once each category had a list of top covariates, these terms remained fixed for the global analysis. During this stage, we compared the top GLMM models for each category against each other, combinations with two categories, and against a global model (top variables from all three categories), again using AIC as our selection tool. Model residuals were assessed visually using the 'DHARMa' (Hartig 2021) and 'gratia' (Simpson 2021).

Finally, top models from each of the four response variables were fitted to GAMs. Models with and without additional smoothing parameters, and models with and without location (latitude and longitude) as a fixed effect (tensor product, duchon splines) were compared for goodness of fit via chi-squared tests (ANOVA) and AIC. Smoothing parameters for indicated variables were assessed for effective degrees of freedom (*edf*). We assumed that an $1 < edf < 2$ indicated a weakly non-linear relationship and edf > 2 indicated a strongly non-linear relationship (Zuur *et al.* 2009). An *edf* value at or near zero indicated the parameter was penalized and completely removed from the final function (select = TRUE argument, Wood

2017). If this occurred, we kept terms in the model without a smoothing parameter instead of dropping them altogether.

RESULTS

Image classification analysis resulted in the correct identification of eligible stands for 60% of survey points (698 / 1162). For one-third of the error (128 / 464), points were located neither in predominantly pine stands nor at the target height. An additional 141 plots (87 trees) were eliminated due to limited forage availability (pine trees recorded but with zero total available shoots) and hence an undefined browsing pressure value. In total, 3,033 pine trees (1,891 in Norway and 1,142 in Sweden) on 557 plots (335 in Norway and 222 in Sweden) were utilized.

In total, 3,033 individual pine trees were analyzed. We recorded 99 instances of bark browsing (38 from the previous winter), and 67 instances of stem breakage (25 from the previous winter). Despite occurring in only 3.3% of trees (n = 101), bark browsing was detected in 14% of eligible plots (57 / 557). Stem breakage was also recorded in 11% of plots, but only 72 trees (2.4%). Top shoot browsing was recorded on 30% of all apical shoots, a third of which (n = 307) were winter browsed only (approximately 31% of plots). The mean number of browsed shoots recorded in the study area was about 3 shoots per tree (maximum of 233), with an average of 33 un-browsed shoots (maximum of 738). Bark browsing (n =74) and stem breakage (n =50) were documented predominantly in Sweden (75% of total occurrences for both types). Browsed winter top-shoots were also found mostly in Norway (n = 200, 65% of total occurrences). Mean browsing pressure values were similar for both countries (13.1% $\pm$0.28 for Norway and 14.8% $\pm$0.29 for Sweden).

Instances of fresh (from the previous winter) bark-browsing (n = 38) and stem breakage (n = 25) were rare. To increase the number of viable model covariates, instances of these types of fresh damage were combined with evidence of these types of damages from past years. While this is not ideal, this increased the total number of model terms (roughly 1 term per 10 occurrences of interest) to seven or eight, including the intercept. Measures of accumulated damage were not utilized for stem breakage models, because a broken stem would most likely result in a 'High' accumulated damage rating. Aspect returned a relatively even sample size between categories (North = 649, South = 889, East = 782, and West = 713).

Overall Predictions

Localized pine density (i.e., in the plot area around the tree), was not returned as a top covariate for any of the four damage types. Snow depth came up as a top 'Environment' covariate for winter top-shoot browsing but was not retained during global model selection. Measures of accumulated damage were included in top models for three damage types at the level of the individual tree ('IndAcc'). No models returned identical covariates, but three of the four damage types returned both the 'Damage' and 'Environment' categories in the final model. Aspect as a categorical variable was the 'Environment' covariate selected most. The weighted average of the season of top-shoot browsing ('PlotWTop') and browsing pressure ('PlotPressure') were each selected twice in the 'Damage' category on the plot-level. Top covariates for each category, as well as the global model selection results, are listed in Table 3. Forest plots of scaled coefficients are provided in Fig. 2. Not all terms were significant in the final models.

Including smoothing parameters on some terms, plus fixed effect of location (latitude and longitude), improved models based on maximum likelihood (ANOVA) and lowered AIC. In total, smoothing parameters were reduced or dropped for four terms (3 in bark browsing and 1 in stem breakage) to account for low effective degrees of freedom (Table 4). GAMs identified potential non-linear relationships for several covariates. The interaction between spruce and birch density in the winter top-shoot browsing model, browsing pressure of the individual tree ('Ind Pressure') in the stem breakage model, and solar radiation in the bark browsing model were estimated to be roughly quadratic (edf $\cong$ 2). Most other covariates had degrees of freedom between 4.0 and 9.0. GAM results are summarized in Table 4.

Density Findings

Localized density of birch species was returned in the winter top-shoot model, but also included an interaction with localized spruce density. This interaction was weakly negative (-0.17 $\pm$0.07; Fig. 2). This relationship is potentially non-linear (Table 4) and is visualized in multiple dimensions in Fig. 3. Birch had the highest effect on winter top-shoot browsing (a 10% predicted probability) when it co-occurred at moderately high densities along with average or below average spruce densities. This same pattern was not seen at similar birch densities with higher-than-average spruce densities.

Snow depth Findings

Snow depth was returned as a top 'Environment' covariate, along with relative elevation (ridges or valleys) for the winter top-shoot browsing model. However, the 'Environment' category was not selected in the final model (Table 3) for this damage type. In addition, snow depth was not correlated to relative elevation, solar radiation received, slope, or aspect.

Prior Damage Findings

Accumulated damage on the individual tree had positive effects on browsing pressure (Low = +1.75 SE ±0.07; High = +2.30 SE ±0.09) and winter top-shoot browsing models (Low = +3.83 SE ±0.58; High = +4.89 SE±0.60; Fig. 2). The effect was neither positive nor negative for bark browsing models (also Fig. 2). Fig. 4 depicts the interaction between two variables, accumulated damage and browsing pressure calculated for the plot, and the predicted probability of top-shoot browsing. At average levels of browsing pressure, there was a 9% probability that the top shoot had been browsed during the past winter for trees at 'Low' levels of accumulated damage, compared to nearly 0% for trees with no documented cervid damage. This more than doubled (over 20%) for trees with 'High' levels of damage.

Shared Covariate Findings

Overall, the 'Stand' category was selected least, and three of the four damage types had the same combination of covariate categories ('Damage' and 'Environment'). There were many differences in covariate selection within these categories. Certain covariates were returned by our model selection process more than others, particularly in the 'Damage' category. Slope and aspect were returned most often in our 'Environment' category. 'Stand' covariates showed the most variation, with none in common between winter top-shoot browsing and browsing pressure, and no stand covariates selected at all for stem breakage and bark browsing. The global model was returned within the ΔAIC threshold only once. By principles of parsimony, and due to the 'Stand' covariates being reduced to 0 *edf* by our GAM analyses, the 'Stand' covariates were subsequently dropped.

Distribution Findings

GAM predictions extended over the entire study area are presented in Fig. 5, with model covariates held at their predicted average or modal value. Winter top-shoot browsing was predicted to occur mostly in the northwestern part of the study area (Norway), with a smaller area of high predicted concentrations in the southeast corner (Sweden). Stem breakage and bark browsing were predicted to occur primarily in the east, with bark browsing having a much smaller predicted extent. Browsing pressure was more uniformly distributed, with several smaller "warm spots" located throughout (Fig. 5).

DISCUSSION

Some of our predictions were validated by this analysis, but there were several unexpected results. The absence of a pine density and snow depth covariates in any model, and the presence of an interaction between birch and spruce density for the winter-top shoot models are discussed in more detail below. While we found evidence for the impact of prior damage on current damage through our category of accumulated browse, we also found evidence that certain types of current damage predicted the occurrence of other damage types. This specific co-occurrence had support from our landscape models as well, and we discuss potential biological mechanisms for these patterns. We tried to contextualize our results in light of recently developed cervid foraging behavior theories and make new predictions about the long-term impacts of these patterns on the landscape. Differing spatial scales, the subjective nature of browsing surveys, and limitations of our study design should also be considered when discussing the importance of our findings.

Our image classification returned 11% of plots as neither at the correct height nor with the correct tree composition. Another 30% of plots returned partial failures, two-thirds of which represented stands within the appropriate height window but lacking pine. Considerations of our study design are partly to blame. The 80-m grid spacing taken directly from Äbin was likely designed with larger stand sizes in mind. Smaller, irregularly shaped stands might have been missed, and it is also possible that we oversampled stand edges. Technicians also noted the presence of large seed trees (mature individuals left behind after harvest) in many ineligible plots, indicating that younger pine age classes had yet to re-establish after recent logging. The accuracy of remote sensing products in this area may be less reliable as spruce becomes favored by landowners and managers (Felton *et al.* 2020). We suggest that new technologies such as drone monitoring or airborne-laser scanners (Melin *et al*. 2015) should be explored to help map this unique habitat type in a cost-effective manner, and that this data be made publicly available.

This study did not explicitly include variables related to animal density of either moose, its ungulate competitors, or predators. We chose not to include this information because accurate animal density estimates, including resource selection functions (RSFs), use many of the same environmental variables that were included in our analysis (Leroy 2021). Gicquel *et al.* (2020) found that the impact of wolf density on browsing damage was small compared to other factors such as presence of deciduous trees, road density, and snow depth. Competition from roe deer (*Capreolus capreolus*) influenced browsing damage at low latitudes in Sweden (Pfeffer *et al.* 2021), but the latitudinal gradient of our study was limited in comparison. Still, the presence or absence of cervid pellets in the plot could easily have been noted during data collection and will be collected in the updated version of the hybrid methodology.

We were surprised to see that pine density was not selected at any stage in our modeling process. We can think of several potential explanations for these findings. Firstly, our analytical framework could be improved. While the categories chosen are inherently arbitrary, all variables in Table 2 have been found to affect browsing damage in previous studies, and we excluded several others (for silvicultural cleaning see Härkönen 1998; for edge effects within stand see Andren & Angelstam 1993; for distance to nearest road and type of road see Loosen *et al.* 2021). Some forms of browsing damage can also be driven by nutrient deficiencies (Faber 1996; Kline *et al.* 2018) which had no covariate proxy in this analysis. We could have used model averaging for two of the four damage types, but small sample sizes for bark browsing and stem breakage prohibited us from using this technique for all damage types.

Ball & Dahlgren (2002) highlight differing spatial scales as contributing to conflicting results of whether tree density plays a role in the probability of damage. Pine density and browsing damages are often scaled up to or measured on the stand-level, whereas we collected information about the area immediately around each tree (plot-level). Both the Äbin and Solbraa sample designs use stands as a management unit, but given the accuracy of our remote sensing data, identifying stand perimeter and area would have been difficult and time consuming. Andre & Angelsatm (1993) found that damage was not significantly related to stand size, however. One interesting difference with our study is that the base observational unit was the individual tree, not squares, stands, or plots; but multiple scales of covariates make inferences from our predictions more difficult. We could have used spatial re-sampling techniques to help reconcile this.

Lastly, pine density has sometimes been correlated to forage availability, and some studies have suggested increasing pine densities in some fashion to offset browsing damage (Andren & Angelstam 1993, Heikkilä & Härkönen 1996, Wallgren *et al.* 2013). Other variables in our analysis potentially served as a better approximation for forage availability, such as the level of accumulated damage. The total number of shoots might also be a better approximation for forage availability and was indirectly accounted in the browsing pressure covariate, which was found to be a top predictor for the other three damage types (Table 3). Tree height might also serve as an indicator of forage availability but was not retained during model selection.

In pine dominated stands, the density of other species played a minor role in predicting winter top-shoot damage for our study area, even though overall effect was small (Fig. 3 and Table 3). The interaction of spruce density with deciduous tree (birch) density was also unexpected. Firstly, what are spruce doing if we specifically selected stands of predominantly pine? Our survey methodology threshold of 10% pine is quite low and done by visual estimate of the stand. We could modify our threshold, (Ball & Dahlgren 2002), but the fact that moose are browsing pines in these low density stands is interesting. Secondly, what is a potential biological mechanism that could explain this pattern? The increased presence of spruce could be a side effect to increased browsing on pine. Moose have been shown to effectively reduce competitor tree densities across several age classes in Canadian spruce plantations, and were even recommended as an alternative management action to mechanical release (De Vriendt *et al.* 2020). Bergqvist *et al.* (2014) found that pine damage increased significantly when birch was overtopping it, and suggested that as a shade intolerant species, birch canopies prevent pine from reaching escape height. Current research is focused on exploring the exact relationship between deciduous trees and pine browsing damage (Zimmermann *et al.* 2022) but remains a complex area of study.

Wallgren *et al.* (2013) found that the most important explanatory variable for recent damage (plot-level) was the presence of previous damage. Our results corroborate these findings at the level of individual trees. There is always a possibility of subjective bias in these types of categorical assessments. Our hybrid methodology worked to counteract this bias by designing accumulated browsing categories based on presence/absence indicators on the current stem, instead of attempting to evaluate future impacts to growth form. We also reduced the number of categories in our final analysis to prevent drawing inferences between categories only one step apart, i.e., observers are more likely to be able to differentiate between trees in the 'Light' category compared to trees in the 'Intense' category. Over the long-term, re-browsing has the potential to create positive feedback loops resulting in higher forage availability (Yovovich *et al.* 2021), but at the worst extremes can result in complete pine dieback and a loss of food altogether.

Interestingly, we also found that damage types can also be strong predictors of each other. This co-occurrence of current damage had some degree of spatial overlap and could certainly be a correlation. Another potential explanation could involve a temporal dimension, and that these damage types interact in a progressive fashion. Increased browsing pressure, when coupled with increased levels of accumulated damages, increased the probability of winter top-shoot browse (Fig. 4) and may cause delayed recruitment to escape height. If high use persists and the trees are unable to cope with the increased level of browse, moose that concentrate in once productive areas could potentially turn to bark browsing, or more energy intensive efforts like breaking large stems to access the top-shoot or inner bark/sap.

Damage types as a progression of increasing severity has circumstantial evidence from our analysis. Browsing pressure was indeed widespread, and the two areas with high predicted occurrence of winter top-shoot browsing both overlapped browsing pressure "warm spots" (Fig. 5). The only hotspot of bark browsing is overlaid with hotspots of all other damage types. Stem breakage proved to be the exception, which was predicted to occur in more continuous bands. Browsing pressure came up as an important predictor for the other three damage types, albeit at different scales (Table 2). For both bark browsing and stem breakage, the weighted average index for season of top-shoot browse was also a top predictor. This sequence of increasing damages might also help explain why stand covariates were largely absent from top models, and why environmental variables had little predictive power in comparison to damage covariates.

Recent studies suggest that cervids and other herbivores may have a landscape memory for productive or good foraging conditions, especially in winter, when resources are scarce. According to new frameworks such as the Adult Learning Hypothesis (Aikens *et al.* 2017), knowledge of these areas might be acquired with age and experience, or the Cultural Transmission Hypothesis (Jesmer *et al.* 2018), knowledge could also be passed down from mother to calf during her seasonal migration or semi-migration. Following this, animals might prefer to over-use known areas, instead of potentially wasting valuable time and energy searching for new areas. A growing body of evidence indicates that moose are able to influence or even regulate their own food supply in this way (Shipley 2010). The current patterns we see could also represent either the end point of a previous long-term process that has slowly removed more preferred deciduous species like willow (Shipley 2010, Stolter 2008) or a starting point for future habitat modifications that may or may not be favorable to current forestry practices.

Few studies have attempted to shed light on how this damage starts in the first place, or how individual moose foraging decisions might start the cycle anew. One way this might occur is through seasonal variation in winter severity, since during mild winters, exploration becomes less energetically costly. If previous browsing damage is a potential factor in driving ongoing damages, years with particularly low snow depths may correspond to increased access and potential establishment of new browsing areas that animals may return to. Snow depth trends over multiple years may also influence the spatial memory and effectiveness of long-term migration routes and animal movement (Merkle *et al.* 2019). Snow depth data from only the previous winter (November 2020 - April 2021) was used in our analysis. Many hotspots were in the south (except for winter top-shoot browsing), below areas of high snow accumulation (Fig. 1). Snow depth might also show lag-effects across years and including snow depth information such as 5- or 10-year minimums might also be an interesting avenue of potential research. Analyzing similar browsing damage data collected in areas with more varied snow accumulation or along a lager latitudinal gradient might return annual snow depth as a top predictor.

Our study was not designed to test a potential link between damage type and severity or over-use, or potential long-term environmental effects on foraging behavior like those described above. More studies would of course be needed, both to confirm these hypotheses and better quantify the time scale these processes operate on. If damage type does indicate increasing severity or a natural progression of overuse, the presence of rare, more severe types of damage (stem breakage or bark browsing) could automatically alert managers and foresters that this area meets or exceeds browsing pressure (Norway) or winter top-shoot thresholds (Sweden; Table 1). If future data is collected, we predict current areas of high browsing pressure and winter top-shoot browsing (for example, between 60.7° N and 12.0° W, Fig. 5) near or around current high use areas might start to record more instances of bark browsing and stem breakage in the future, barring natural disturbances or human development.

Predictors that influence light availability (slope, aspect, and solar irradiance) were returned in several top models. As mentioned previously, pine is a shade-intolerant species (Bergqvist *et al.* 2014) and pine is traditionally thought to by Scandinavian foresters to have an advantage on nutrient poor or sites with intermediate soil fertility (Holmström *et al.* 2018). This traditional preference might also explain why soil productivity was lacking from our top models. If light availability is a limiting factor for pine in this system, areas that afford the light in the winter might be able to better support young pine age classes. Fluctuations in light availability can be especially pronounced in northern latitudes that experience strong seasonal photosynthetic cycles. We would expect aspect and irradiance to be correlated however, which was not the case. This is again, perhaps due to differences in spatial scale, as the former was on a 250-m resolution and the latter on a 1x1 km resolution. The general effect of these light availability covariates was again low compared to damage predictors (Fig. 2).

Contrary to our predictions, winter top-shoot browsing was highest outside the known winter concentration area along the Swedish/Norwegian border. Local reports corroborate this finding and suggest browsing damages were potentially severe in the northwest. Unfortunately, we also lack robust samples from the winter-concentration area along the border. This likely is the result, at least in part, from errors in our remote sensing analysis discussed earlier, and partly due to the inability of field teams to cross the geographic border during the COVID-19 pandemic. Lower predicted probabilities in certain areas might also reflect increasing model uncertainty as distance increases from relatively rare events such as a broken stem.

More sophisticated landscape models could be particularly useful to identify damage in previously unknown areas or help quantify degree of damage for forest management in areas where intensive field surveys are cost prohibitive. Combined with a severity index (if one exists), managers could more easily detect potentially at-risk areas, and researchers could potentially find new areas of animal use. Landscape models could also serve as an important tool for testing ecological hypotheses regarding the long-term effects of moose foraging behavior. Understanding 'moose as forester/farmer" phenomenon, and what it means for the long-term viability of their habitat, is paramount for both future researchers and management.

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Table 1. Comparing browsing damage methods in Norway and Sweden.

	NORWAY	SWEDEN
Damage Indices	Number of Browsed Shoots	% Fresh Damage (Top-shoot, bark browsing, and stem breakage)
Goal for Monitoring	Healthy Moose Populations	Healthy Forest Stands
Name of Method	Solbraa	Äbin
Management Thresholds		
Green	0-20% Light Damage	0-5% Tolerable
Yellow	20-30% Moderate Damage	5-10% Acceptable (if not sustained for more than 1 year)
Red	30-40% Severe Damage	10-20% Critical
Black	>40% Forest threatened	>20% Forest threatened mature forest unlikely

Table 2. Covariates used in model selection, separated into three categories.

Covariate Name	Scale	Units	Data Sources/Notes
Stand Covariates			
Localized Pine Density	Plot Level	# pine/38.5 meter^2	Collected summer 2021
Productivity	Plot Level	Very Poor, Poor, Moderate, Good	Derived from dominant field vegetation layer
Localized Spruce Density	Plot Level	# spruce/38.5 meter^2	Collected summer 2021
Localized Birch Density	Plot Level	# birch/38.5 meter^2	
Average Pine Height	Plot Level	meters	
Pine Height	Individual Tree	meters	
Environmental Covariates			
Snow Depth	1x1 km grid cells	millimeters	seNorge NVE snow model
Aspect	250 x 250 m grid cells	North, South, East, West	EU DEM v1.1
Elevation	250 x 250 m grid cells	±meters over average	EU DEM v1.1
Road Density	1x1 km grid cells	kilometers road/kilometer^2	N50 Dataset
Slope	250 x 250 m grid cells	degree	EU DEM v1.1
Solar Radiation	250 x 250 m grid cells	Kilowatt-hours/m^2 January 1	EU DEM v1.1
Prior Damage Covariates			
Weighted Index Average of Accumulated Damage	Plot Level	1: Light LOW 2: Moderate 3: Intense HIGH 4: Destroyed 0: Other/ Undamaged NO DAMAGE	Collected summer 2021
Accumulated Damage Score (factor)	Individual Tree		
Weighted Index Average of Season of Top Shoot Browse	Plot Level	1: Summer Only 2: Winter Only 3:Both Winter & Summer 0: Other / Older Damage	Collected summer 2021
Season of Top Shoot Browse (factor)	Individual Tree		
Browsing Pressure	Plot Level	Total Shoots Browsed/ Total Shoots Browsed + Unbrowsed	Collected summer 2021
	Individual Tree	Shoots Browsed / Browsed + Unbrowsed Shoots	*Excluded from Winter Top-Shoot Models*

Table 3. List of the top GLMM covariates for each browsing damage type.

Response Variable	Top Covariates: Stand	Top Covariates: Environment	Top Covariates: Previous Damage	ΔAIC ≤ 2
Top-Shoot Winter Browsed?	Birch Density * Spruce Density	Relative Elevation Snow Depth	IndACC[1] + Plot Pressure	Global **Damage + Stand**
Stem Broken?	*NONE*	Avg Slope + Relative Elevation + Aspect	PlotWTop[2] * Ind Pressure	**Damage + Environment**
Bark Browsed?	*NONE*	Aspect * Solar Radiation	IndACC + Plot Pressure + PlotWTop	**Damage + Environment**
Browsing Pressure (rate)	Productivity * Plot Avg Height Pine	Aspect + Avg Slope + Road Density	TopShoot Age[3] + IndACC + PlotWTop	**Damage + Environment**

[1] Categorical variable: accumulated damage score for the individual tree (None, Low, or High)
[2] Continuous variable: Weighted average of age of estimated top-shoot browse for all pine trees measured in the plot
[3] Categorical variable: age of the browsed top-shoot for the individual tree (None, Summer, Winter, Both)

Table 4. List of linear and non-linear covariates in top models for each browsing damage type.

Response Variable	Linear Covariates	Non-Linear Covariates	Degrees of Freedom	R-sq (adj) and % Deviance Explained
Top-Shoot Winter Browsed?	IndACC	Plot Pressure	5.0	**0.171 / 25.2%**
		Birch Density * Spruce Density	1.7	
		Latitude*Longitude	7.2	
Stem Broken?	Aspect Slope Relative Elevation	Ind Pressure* PlotWTop	3.8	**0.055 / 14.9%**
		Latitude*Longitude	5.6	
Bark Browsed?	IndACC Aspect PlotWTop Plot Pressure	Latitude*Longitude	11.2	**0.0923 / 21.4%**
		Solar Radiation	1.6	
Browsing Pressure (rate)	Top-Shoot Age IndACC Aspect	Average Slope	8.6	**0.593 / 64.6%**
		Road Density	18.8	
		PlotWTop	7.8	
		Latitude*Longitude	31.0	

Table 1: Both Norway and Sweden employ a "traffic light system" to categorize browsing damage severity. Sweden focuses on instances of fresh browsing, whereas Norway focuses on browsing pressure on all available shoots. The management thresholds are particularly striking when compared side by side, as the "moderate" damage category in Norway corresponds to the most unacceptable level of damage in Swedish forests.

Fig. 1. Map of the study area exploring moose browsing damage on pine in a cross-border context between Norway and Sweden. Snow depth is roughly contoured by intervals of 150 mm (see Table 2 for data source) and averaged from between mid-October and mid-May 2021. In total, 313 sampling squares each 1x1 km were spaced throughout, and each square was then divided into an 80x80 m grid. Finally, this grid was overlaid with potential eligible stand polygons to obtain browsing plot locations.

Table 2: List of covariates used in model selection for different types of moose browsing damage, their relative spatial scale, units, and data sources. Tree density and average height of all stems in the plot were dropped from further analysis due to high correlation with pine density and pine height variables.

Table 3: List of top covariates in intra- and inter-category model selection. Bolded names in the final column indicate the top model selected for each response variable. Each category was limited to a maximum of three variables carried forward to the global modeling analysis. For bark browsing and stem breakage, covariates in the "Stand" category did not improve fit when compared to models with only the random error term and were dropped from further analysis.

Fig. 2. Forest plots of top GLMMs for all four response variables describing moose browsing damage on pine. Purple terms indicate positive relationships and green terms indicate negative relationships, separated by the blue zero line. Stars denote level of significance as reported by the model output summary. Terms with confidence intervals that overlap the zero line are considered to have neither an positive nor negative effect on the slope of the linear model.

Table 4: List of GAM analysis results for each of the top models listed in Table 3. Models were tested for linearity by first applying the GAM functional framework without any smoothed terms and then compared (via AIC and ANOVA) to models with smoothed terms, and to models with smoothed terms and location as a fixed effect.

Fig. 3. The effects of the interaction between spruce density and birch density on probability of winter top-shoot browsing by moose on pine. The x- and y-axes are standardized on their z-score (standard deviations above mean) and both increase "towards" the viewer (low corner of the box). Birch had the maximum effect on winter top-shoot browsing (10% probability) at moderately high densities (2-4 standard deviations above mean) with average or below-average spruce densities. This pattern quickly disappeared at higher spruce densities.

Fig. 4. The predicted probability of winter top-shoot browse by moose on individual pine trees at different browsing pressure levels of the entire plot. Even at similar levels of browsing pressure (scaled variable), increasing accumulated damage levels increased the probability of winter top-shoot browsing.

Fig. 5. Spatial distributions of browsing damage type based on GAM model predictions. Light (yellow and orange) areas indicate higher concentrations of that particular damage type, dark (purple and red) areas indicate lower concentrations. Gray areas indicate model uncertainity, which generally correspond to areas with limited eligible plots due to lack of pine or forest (such as the large bog complex in the north-central part of the study area). Model predictions were limited to spatial extent within the bounds of the dataset. All covariates are held at their mean predicted values, or modal/median value for relevant categorical variables (ex: South aspect, Low accumulated damag level, Unbrowsed top-shoot).

Fig. 1.

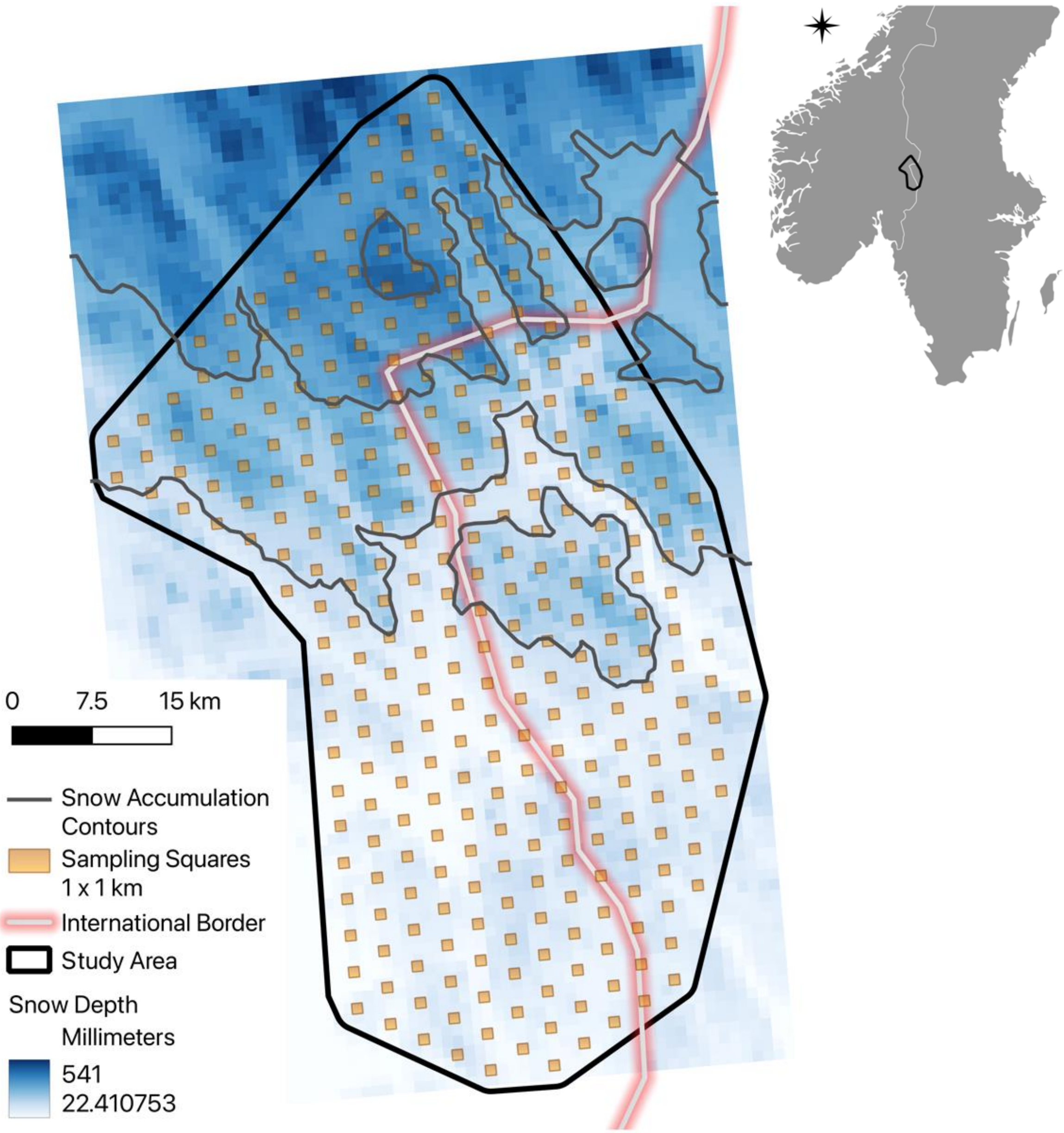

0
7.5
15 km
Snow Accumulation Contours
Sampling Squares 1 x 1 km
International Border
Study Area
Snow Depth Millimeters
541
22.410753

Fig. 2.

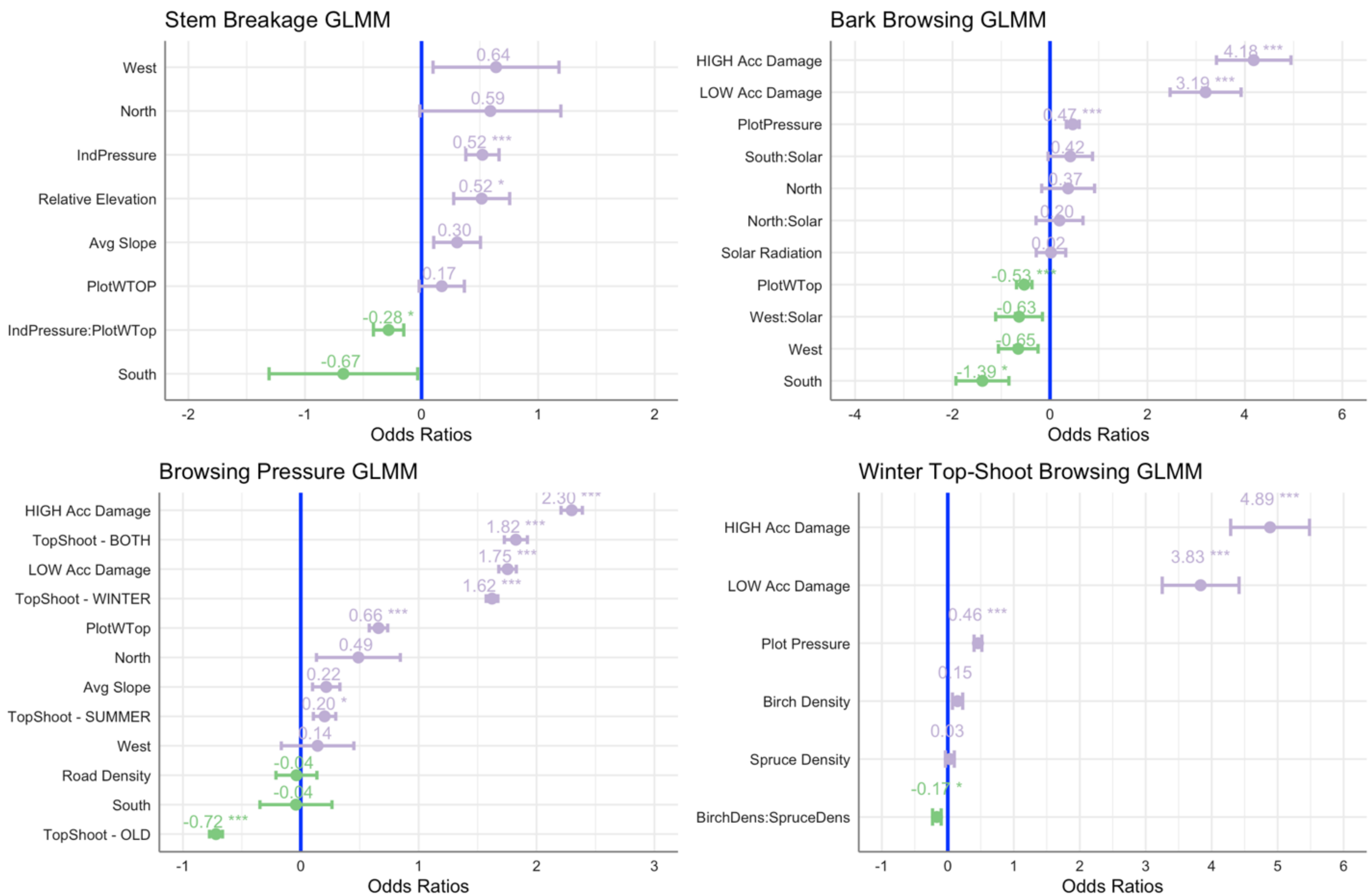

Stem Breakage GLMM
West
North
IndPressure
Relative Elevation
Avg Slope
PlotWTOP
IndPressure:PlotWTop
South
0.64
0.59
0.52 ***
0.52 *
0.30
0.17
-0.28 *
-0.67
-2
-1
0
1
2
Odds Ratios
Bark Browsing GLMM
HIGH Acc Damage
LOW Acc Damage
PlotPressure
South:Solar
North
North:Solar
Solar Radiation
PlotWTop
West:Solar
West
South
4.18 ***
3.19 ***
0.47 ***
0.42
0.37
0.20
0.02
-0.53 ***
-0.63
-0.65
-1.39 *
-4
-2
0
2
4
6
Odds Ratios
Browsing Pressure GLMM
HIGH Acc Damage
TopShoot - BOTH
LOW Acc Damage
TopShoot - WINTER
PlotWTop
North
Avg Slope
TopShoot - SUMMER
West
Road Density
South
TopShoot - OLD
2.30 ***
1.82 ***
1.75 ***
1.62 ***
0.66 ***
0.49
0.22
0.20 *
0.14
-0.04
-0.04
-0.72 ***
-1
0
1
2
3
Odds Ratios
Winter Top-Shoot Browsing GLMM
HIGH Acc Damage
LOW Acc Damage
Plot Pressure
Birch Density
Spruce Density
BirchDens:SpruceDens
4.89 ***
3.83 ***
0.46 ***
0.15
0.03
-0.17 *
-1
0
1
2
3
4
5
6
Odds Ratios

Fig. 3.

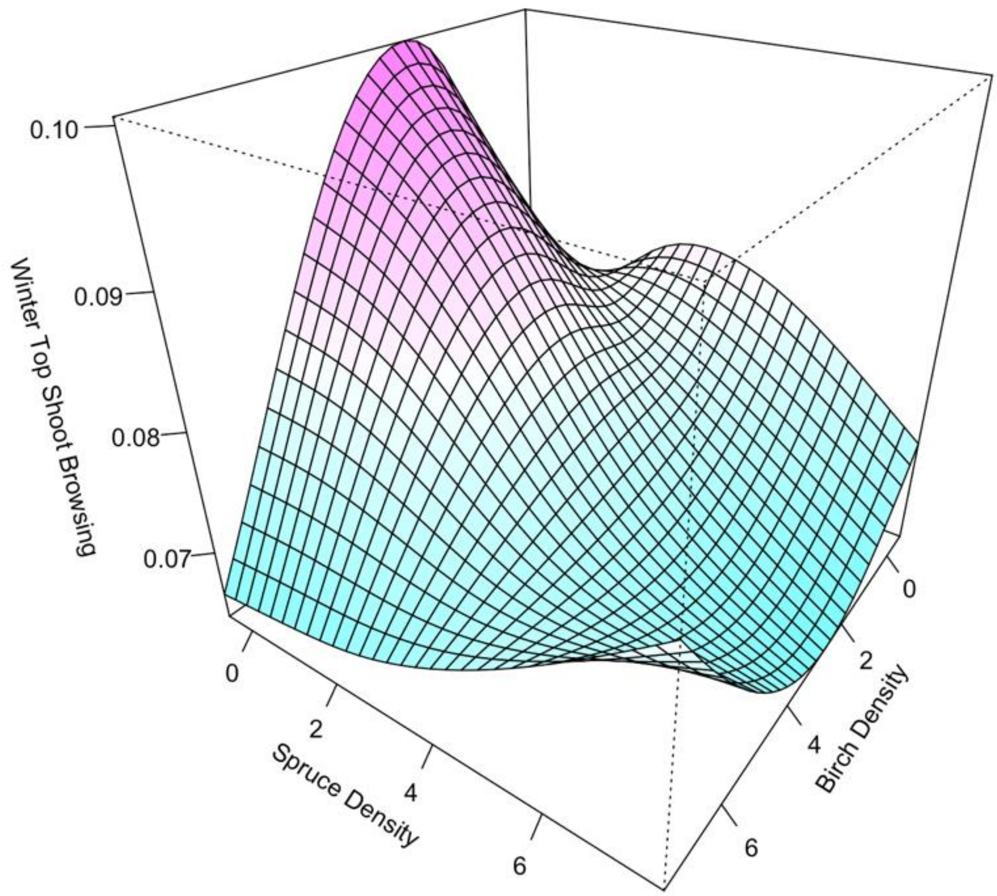

0.10
0.09
0.08
0.07
Winter Top Shoot Browsing
0
2
4
6
Spruce Density
0
2
4
6
Birch Density

Fig. 4.

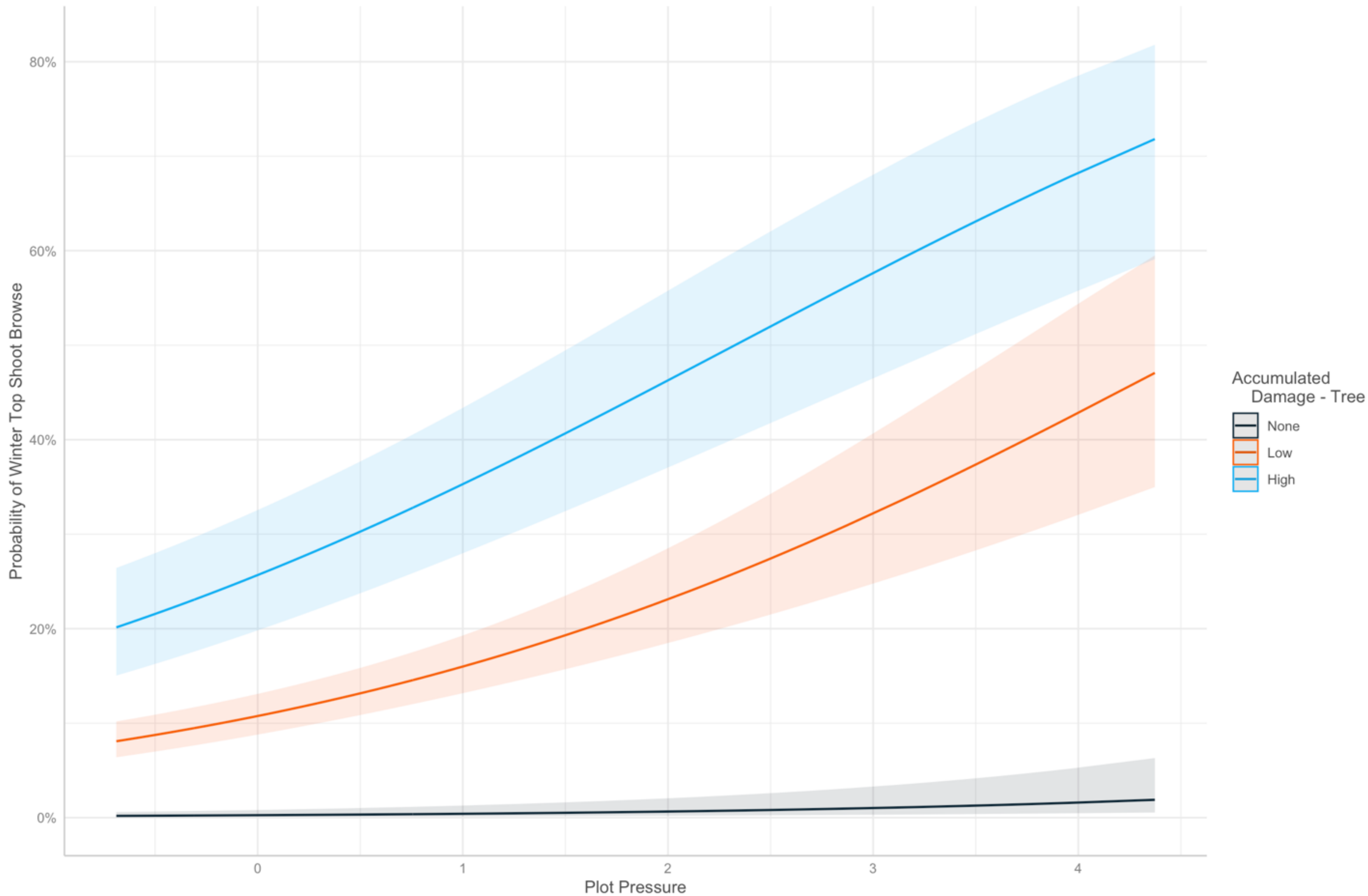
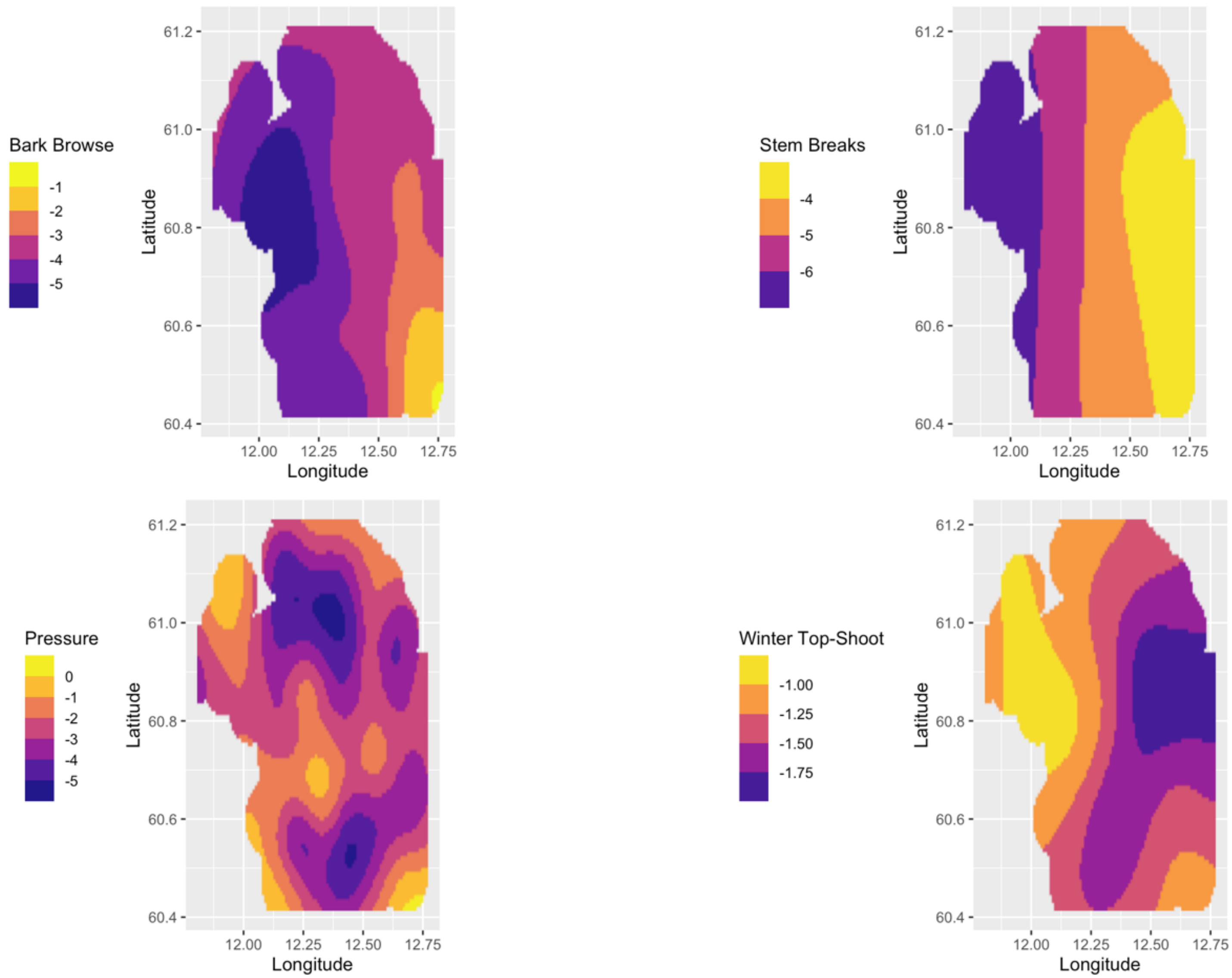

80%
60%
40%
20%
0%
Probability of Winter Top Shoot Browse
0
1
2
3
4
Plot Pressure
Accumulated Damage - Tree
None
Low
High

Fig 5.


Bark Browse
-1
-2
-3
-4
-5
Latitude
61.2
61.0
60.8
60.6
60.4
12.00
12.25
12.50
12.75
Longitude
Stem Breaks
-4
-5
-6
Latitude
Longitude
Pressure
0
-1
-2
-3
-4
-5
Latitude
Longitude
Winter Top-Shoot
-1.00
-1.25
-1.50
-1.75
Latitude
Longitude

MANUSCRIPT GUIDELINES FOR CONTRIBUTORS TO *ALCES*

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ABSTRACT: General guidelines for the preparation of manuscripts submitted to *Alces* appear inside the front cover of each issue, beginning with Volume 24 in 1988. This paper provides more detailed guidelines for the preparation of *Alces* manuscripts. To expedite the publication process, contributors should submit manuscripts in the format and style presented in these guidelines.

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Key words: *Alces*, authors, contributors, format, guidelines, instructions, manuscript, preparation

The number of manuscripts submitted for publication in *Alces* has grown considerably. Contributors have been encouraged to follow the "Manuscript Guidelines for *The Journal of Wildlife Management*" (Ratti and Ratti 1988). Those guidelines remain an important reference for contributors to *Alces*. However, there remain a number of differences in style and format between *Alces* and *The Journal of Wildlife Management*. Some of these exceptions are noted inside the front cover of each issue of *Alces*, beginning with Volume 24 in 1988. Yet there are numerous, less noticeable differences between the two journals, all of which require editing and reformatting of manuscripts to achieve consistency of style and format among papers appearing in the journal. This work is an expense and slows the publication process. Therefore, we have developed more detailed guidelines for the preparation of *Alces* manuscripts. Contributors should check the most recent issue of *Alces* for changes that may supersede these guidelines, as well as the name and address of the current Editor receiving manuscripts. Updates to these guidelines are also posted on the *Alces* World Wide Web site. Beginning with Volume 32 in 1996, the *Alces* website address is given on the inside back cover of each issue and on all reprints obtained directly from contributing authors. The current *Alces* website address is http://www.lakeheadu.ca/~alceswww/alces.html.

EDITORIAL POLICY

Alces publishes original manuscripts describing studies of the biology and management of moose (*Alces alces*) throughout their circumpolar distribution. Some manuscripts originate as papers presented at the annual North American Moose Conference and Workshop or the International Moose Symposium, but works may be submitted directly to the Editors at any time. Each is allocated to an Associate Editor who assigns the manuscript to at least two reviewers knowledgeable about the subject. Reviewers judge submitted manuscripts on data originality, ideas, analyses, interpretation, accuracy, conciseness, clarity, appropriate subject matter, and on their contribution to existing knowledge.

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MANUSCRIPT PREPARATION

In developing these guidelines we have assumed that prospective contributors have access to a computer word processor for manuscript preparation. If a submission is produced manually, authors should still adhere to these guidelines as closely as possible. After revision, accepted manuscripts must be submitted in digital form (i.e., on diskette), following these guidelines. Authors should refer to a recent issue of *Alces* for details of layout, especially for tables and reference lists. Manuscripts that do not conform to the guidelines outlined below may be returned to the author for modification.

General Presentation

Copies. — Four (4) paper copies of the manuscript with all illustrations must be provided for the review process. Do not submit copies from poor-quality dot matrix printers.

Paper size. — Print the manuscript on one side of good-quality white paper, 21.5 x 28.0 cm (8.5 x 11 inches) or metric size A4.

Page margins. — Maintain 2.5-cm (1-inch) margins on all pages, including tables and illustrations.

Line spacing. — Except for the date and corresponding author information (see below), all parts of the manuscript must be typed double spaced.

Justification. — All text should be left-justified, except for page numbers and the *Alces* volume information (see below) which are right-justified.

Hyphenation. — Do not break and hyphenate words at the right margin. A hyphen may appear at the right margin only if it is part of a hyphenated word or phrase (e.g., 2-year-old bulls).

Font and font size. — Use a common font, such as Times Roman or Helvetica, with a font size of at least 10 pts (11 pts is currently preferred). The same font and font size should be used throughout for all text, including tables.

Type style. — Do not underline words to be set in italics. Use the text formatting feature available in word processing software to type the text in italics where required. Italics should be used for scientific names, Latin words and abbreviations (e.g., *et al.*, but not e.g. or i.e.), statistical symbols (e.g., n, P, $\overline{X}$, r, F, etc.), and names of publications given in the text (e.g., *Alces*). Do not use italics for names of publications given in the REFERENCES section (see below). Upper-case letters and **bold**-faced type should only be used as indicated in these guidelines.

Indents. — The first line of each paragraph must be indented 5 spaces. Tertiary headings are also indented 5 spaces as part of a paragraph (see below). The second, and subsequent lines of table titles, subheadings within tables, footnotes, and reference citations should not be indented (see below) in submitted manuscripts. Indents for these types of text will be added during final production for printing.

Page numbers. — Except for the first page of the manuscript, all pages must be numbered consecutively, including tables and figure captions. Beginning on the second page, the running head (see below) should be typed in the upper left corner and the page number (starting at "2") should appear in the upper right corner.

Footnotes. — Text footnotes should only be used at the bottom of the first page to provide the current address of an author when it differs from the address at the time of the study. The footnote appears immediately below a left-justified solid line of 10 characters, and begins with the numerical superscript corresponding to the author's name followed by "Present address:". The footnote then continues with the address information. If an address is longer than a single line, do not indent the second and any subsequent lines. If there are ≥ 2 authors with address changes, each new address should begin on a new line, and is preceded by the superscript corresponding to the appropriate author followed by "Present address:" and the address information. Postal or zip codes should be included. Table footnotes are discussed below.

Organization

Date and corresponding author. — The manuscript should begin on the first page with the date (changed with each revision), corresponding author's name, address, and telephone number, single-spaced in the upper left corner. If available, the author's fax number and electronic mail address should also be provided. Thereafter, all text is double-spaced.

Running head. — The running head (RH) is left-justified and appears on a single line following the corresponding author information. Begin the line with RH followed by a colon and a single space. The remainder of the line is limited to 45 characters (including spaces), typed in upper-case letters. The RH includes a brief description of the paper followed by a hyphen and the last name(s) of 1 or 2 authors. If there are 2 authors, separate their last names with "AND". Use the first author's last name followed by "*ET AL.*", if there are ≥ 3 authors (e.g., RH: *ALCES* MANUSCRIPT GUIDELINES - RODGERS *ET AL.*).

Title. — The title begins left-justified on the next line following the RH. The title should be typed in upper-case **bold** letters, and should not include abbreviations. The title must be short (≤ 10 words) and representative of the article's content. Longer titles may be acceptable if shorter titles force awkward construction or fail to communicate content.

Author name(s). — The next line provides the name(s) of the author(s), left-justified, in upper- and lower-case **bold** letters. If there are 2 authors, separate their last names with "and" (in **bold** letters). If there are ≥ 3 authors, precede the last author's name with ", and" (in **bold** letters). If there are ≥ 2 authors with different addresses, these are indicated by superscripts at the end of each author's last name. A single superscript, or a second superscript separated from the first only by a comma (no space), following an author's last name may also be used to indicate an address change given in a footnote (see above).

Author address(es). — Beginning on the next line, type the address(es) of the author(s) at the time of the study left-justified in upper- and lower-case regular letters (i.e., do not use bold type). If there are ≥ 2 authors with different addresses, their addresses should be given in the same order as in the author name(s) line (above). Each address should be preceded by the superscript corresponding to the appropriate author(s), and each address should be separated with a semi-colon. Present address(es) should be indicated in a footnote (see above), if different from the time of the study. Include postal or zip codes.

Abstract. — After leaving a single blank line, type ABSTRACT, left-justified in upper-case regular letters, followed by a colon and a single space. Begin typing the abstract after the single space on the same line. The abstract should be as concise as possible. Present it in one paragraph and do not use abbreviations or literature citations. The abstract should indicate the problem studied or the hypothesis tested, the most important results, and any major conclusions or interpretations drawn from the work. Description of methods should be brief unless new or much-improved techniques are reported.

Volume identification. — The *Alces* volume identification is right-justified on the line following the abstract. Type ALCES VOL. 00 (0000) pp. 000 - 000 on this line, right-justified.

Key words. — After leaving a single blank line, type Key Words followed by a colon and a single space, left-justified in upper- and lower-case **bold** letters. Following the single space, use regular type to provide 6-12 words in alphabetical order that best describe the major topics presented in the paper. Below the key words, draw a solid black line (1 pt in width) across the page between the margins. Leave a blank line below this solid line and begin typing the first paragraph of text , indented 5 spaces from the left margin (i.e., do not insert a section heading or page break to start a new page).

Headings and major sections. — Similar to this paper, 3 levels of headings are commonly used in *Alces* manuscripts: (1) primary section headings are centred, in upper-case **bold** type; (2) secondary headings are left-justified, in **bold** type, with only the first letter of each word in upper-case; and (3) tertiary headings are indented 5 spaces as part of a paragraph, in **bold** type, with only the first letter of the first word in upper-case (except where proper names are used), and are followed by a period and 2 hyphens. Except for the introduction, all major sections should be identified by primary headings.

Alces publishes papers on a wide range of subjects including natural history (e.g., food habits, habitat use), morphology, taxonomy, physiology, parasitology, population dynamics, modelling, evaluations of statistical techniques, research methods, ecosystem dynamics, management, law enforcement, education, economics, administration, philosophy and other similar topics. Consequently, there is considerable flexibility in the organisation and labelling of manuscript sections. In most cases, however, manuscripts should be organised in a traditional format that includes an introduction, STUDY AREA (if pertinent), METHODS, RESULTS, DISCUSSION, ACKNOWLEDGEMENTS, and REFERENCES. Regardless of organisation and labelling, do not insert page breaks to begin a new section at the top of a new page. Tables, figure captions and illustrations should appear on separate pages following the REFERENCES (see below).

The introduction, without a heading, follows the solid line and the blank line below the key words (see above). The introduction should be limited to the scope, purpose and rationale of the work, definition of the problems, and the reasons or perspective of the study. A concise literature review related to the paper's main topic may be included, but should only be sufficient to orient the reader and place the work within a more general context.

If the work involves field studies, a description of the STUDY AREA should follow the introduction, separate from the METHODS section. Typically, this description may include the geographic location of the study, habitat types, etc., but should not divulge the exact location of rare, threatened, or endangered species. Papers concerning specific sites should include a map locating the study area within a region, country, or continent. Use the past tense to present study area descriptions.

The METHODS section should briefly describe relevant procedures, equipment, and techniques. Dates, sampling periods, research or experimental design, and methods of data analysis should be included. Where possible, authors should refer to the literature for methods already published, then indicate any deviations they have made from those methods. New techniques should be identified and explained in sufficient detail to make them repeatable. Brand names of commercially available equipment or chemical products (with the company name and location, separated by a comma, in parentheses) should be provided. Methods should be presented in the past tense.

Use the RESULTS section to highlight findings presented in figures or tables, avoiding repetition of information that should already be clear. Only those questions raised in the purpose of the work should be addressed. The findings should be organised in the same logical sequence as in the introduction and METHODS sections. In most cases, results should be presented in the past tense.

The DISCUSSION should indicate the main contributions of the study, interpretation of the findings, and comparisons to other published work. Results should not be repeated and only the most important findings should be addressed. Systematic discussion of every aspect of the research is unnecessary. Reasonable speculation and directions for further research may be included. The scope, significance, and general conclusions of the study should end the discussion.

Limit the ACKNOWLEDGEMENTS to those who have contributed substantially to the scientific and technical aspects of the research, granted financial support, or helped improve the quality of the manuscript.

Authors are responsible for the accuracy of all information given in the REFERENCES section. All references must be checked against the original article and must be referred to in the text by the name-and-year system (see below). Reference styles for literature citations in *Alces* are given below.

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Present each table on a separate page, following the REFERENCES section. Continue to provide the running head and consecutive page numbers at the top of each page. All tables should be numbered and presented in the order in which they are cited in the text. Prepare tables in the same font and font size as used in the text. Titles and all parts of tables must be typed double-spaced. Tables should be constructed to fit the width of the page (21.5 cm), leaving 2.5-cm margins on all sides (i.e., 16.5 cm wide). Wider tables may be accommodated by turning the page sideways (i.e., "landscape" page orientation) and fitting the table to the length of the page (28.0 cm), again leaving 2.5-cm margins on all sides (i.e., 23.0 cm wide). Authors must clearly indicate when a table runs to more than 1 page (e.g., type "Table 1 continued...." at the bottom and top of each page).

Table titles begin with the word "Table" left-justified in regular letters, followed by the table number and a period. Leave a single space on the same line and begin typing the title. End the title with a period. If the title is longer than a single line, do not indent the second and any subsequent lines. The titles must be concise and clear so a reader can understand the table without referring to the text (i.e., should "stand alone"). Typically, the title will include the names of variables and organisms measured, the measurement unit(s) (in parentheses), and places and dates of sampling. Abbreviations should not be used in table titles. Footnotes should be used to reduce the complexity of table titles and provide further details (see below).

On the line below the table title draw a single horizontal line across the page between the margins. Additional horizontal lines are then used to separate column headings from the body of a table, but should not appear in the body itself. A single horizontal line is also drawn across the page between the margins below the last row of a table. No vertical lines should be present in a table.

Table columns must be generated with tab settings or a table editor. Do not use spaces (i.e., the space bar) to columnate entries. Column and row headings should not run into data fields. Capitalise the first word in a heading and do not end headings with a period. Row headings should be typed flush with the left margin and each level of subheading should be indented 2 spaces relative to the row above. Column headings should be centred in their respective column. Wording in columns should appear flush with the left boundary of a column. Integers should be typed flush with the right boundary of a column. Other numerical entries should be vertically aligned using the decimal point or another alphanumeric character (e.g., ±, =, ≥, ≤, -, etc.). Authors must ensure all numbers in a column are reported with the appropriate level of precision (i.e., significant digits). Dashes may be used to indicate missing values. Do not use zeros unless an actual value of 0 was measured, and then indicate the level of precision by reporting the appropriate number of significant digits (e.g., 0, 0.0, 0.00, etc.).

Footnotes in tables should be designated with asterisks for probability levels (i.e., *P<0.05, **P<0.01, ***P<0.001) or numerical superscripts. Starting at "1", numerical superscripts should follow consecutively through the title, then left-to-right, and then down. Authors must ensure that all superscripts in the title and table match an appropriate footnote below the table. The first footnote appears left-justified immediately below the horizontal line at the bottom of the table, and begins with an asterisk or numerical superscript. The line is then continued with the footnote information. If a footnote is longer than a single line, do not indent the second and any subsequent lines. Each new footnote begins on a new line, and is preceded by its corresponding superscript. Descriptive material not requiring a specific footnote may be placed under a table as a general note, to reduce complexity of the title and table. In place of an asterisk or numerical superscript, type "Note" followed by a colon and a single space, left-justified in upper- and lower-case **bold** letters, then type the information.

Figure captions and illustrations. — Illustrations should not repeat data presented in tables. Refer to figures in the text using "Fig." followed by the figure number. Begin typing the figure captions on a new page following the last table (or REFERENCES section, if there are no tables). Continue to provide the running head and consecutive page numbers at the top of each page. All figure captions should be numbered and presented in the order in which they are cited in the text. Figure captions must be typed double-spaced and use the same font and font size as used in the main text.

Figure captions begin with "Fig." left-justified in regular letters, followed by the figure number and a period. Leave a single space on the same line and begin typing the figure caption. If the caption is longer than a single line, do not indent the second and any subsequent lines. Each figure caption should begin on a new line. Captions must be concise and clear so a reader can understand the illustration without referring to the text (i.e., should "stand alone"). Footnotes and abbreviations should not be used in figure captions. Complex symbols or keys should be incorporated in a concise legend on the illustration itself, rather than in the figure caption.

Illustrations are either photographs or line-drawn figures. For the review process, good quality photocopies or laser prints of line-drawn figures can be submitted and the originals retained. Figures printed on dot matrix printers are not acceptable. Computer-generated graphs vary in quality. Some may be judged unsuitable, and originals may have to be prepared using traditional graphic art techniques. Xerographic copies of photographs are usually not acceptable, even for the review process. In either case, for final printing of the journal (see below), all illustrations must be of the highest professional quality to ensure proper reproduction after electronic scanning.

Prepare one illustration per page. Identify each illustration by printing the author's name and the figure number on the back in soft pencil. If it is not obvious, also indicate the orientation of the illustration on the back. Each illustration (either a photograph or line-drawn figure), or group of illustrations, should be planned to fit into the area of either 1 (67 mm) or 2 (138 mm) columns of text. Illustrations that can be reduced to single-column width are preferred. Seldom should there be reason to consume a whole page for 1 illustration (maximum length, 190 mm).

Only essential labelling should be used on line-drawn figures, with detailed information given in the caption. Shading in figures should be distinct. All lines must be sufficiently thick for good reproduction, and all symbols, superscripts, subscripts, decimal points, and periods must be well-proportioned to the rest of the figure and large enough to allow for reduction. Letters and numbers on reduced figures must remain legible and be no less than 1.5 mm high after reduction. Wherever possible use uppercase letters for labelling since they are more legible when reduced. Use a clear sans serif font (e.g., Helvetica or Arial) made with a printing device or from sheets of printed characters. Do not use a typewriter. The same size and font of lettering should be used for all figures in the manuscript.

Photographs must be of high contrast and printed with a matte finish. Lettering or numbering must be made from sheets of printed characters and must contrast highly when superimposed on photographs. Do not use a typewriter. A scale bar should be used to indicate magnification if size is important. Similar to line-drawn figures, size and proportions of annotations must be carefully considered since photographs must also be reduced to fit either 1 (67 mm) or 2 (138 mm) columns of text.

General Style And Usage

Numbers and units. — Use digits for numbers (e.g., 3, 27) unless the number is the first word of a sentence, in which case it is spelled out. Spell out ordinal numbers (e.g., first, third) and numbers used as pronouns (e.g., one) or adverbs. Hyphenate number-unit phrases used as adjectives (e.g., 2-year-old bulls), but not those used as predicate adjectives (e.g., plots were 5 m^2). Insert commas in numbers ≥ 1,000, except for pages in books, clock time, or year dates. Do not insert a comma or hyphen between consecutive, separate numbers in a phrase (e.g., 25 3-m^2 plots). Never use naked decimals (i.e., use 0.01, not .01). Use symbols or abbreviations (e.g., %, ha) for measurement units that follow a number, unless the number is indefinite (e.g., thousands of hectares), is a "0" (zero) standing alone, or is the first word in a sentence. In such cases, spell out the number and unit name. Use fractions only where conversion to decimal proportions misrepresents precision.

Times and dates. — Use the 24-hour system: 0001 through 2400 hours (midnight). Date sequence is day-month-year, without punctuation (e.g., 9 April 1997). Use an apostrophe for plural dates (e.g., 1990's). Spell out months, except in parentheses, tables, and figures, where 3-letter abbreviations are used with no period (e.g., 9 Apr 1997).

Statistics. — Roman letters used as symbols for statistics, tests, or variables (e.g., *n*, $\overline{X}$, *r, F, t, Z, P, X*, etc.) should be typed in italics, not underlined. Numbers, names of trigonometric and transcendental functions, or abbreviated statistical terms (e.g., ln, e, exp, lim, min., max., SD, SE, CV, df, etc.) should not be italicised. Greek letters (e.g., χ, α, μ, ∞, π, etc.) should be typed as such using the appropriate font available in most computer word processors.

Insert a space on both sides of symbols used as "conjunctions" (e.g., $n = 25$, $P = 0.003$), but close the space when used as "adjectives" (e.g., >10 moose). Where possible, report exact probabilities (e.g., $P = 0.052$, not $P > 0.05$). Subscripts precede superscripts (e.g., X_i^2) unless the subscript includes >2 characters (e.g., $X^2{}_{cow}$).

Report results of statistical tests by giving the calculated value of the test statistic, the associated degrees of freedom (df), and the probability of obtaining the calculated value of the test statistic (e.g., $t = 2.47$, 1 df, $P = 0.013$, $F = 33.10$; 3, 12 df; $P = 0.01$, etc.). Calculated values of test statistics and associated probabilities should be reported with a maximum of 4 (but usually 2) significant figures. Scientific notation should be used to report very large or small values (e.g., $P = 0.00002$ should be reported as $P = 2.0 \times 10^{-5}$). A measure of dispersion and the sample size should be indicated with measures of central tendency (e.g., $\overline{X} = 5.3$, SE = 2.13, $n = 35$).

Equations. — Regression equations can be incorporated in the text. Variable names in regression equations should be spelled out if they have not been previously defined in the paper. Other equations should be centred on the page and typed triple-spaced. They must be identified by a number in parentheses placed flush with the right margin. In the case of a particularly long equation that may have to run on >1 line, authors should break the equation for column-width printing (67 mm).

Measurement units. — Always use Système International d'Unités (SI) units and symbols. British units should be given in parentheses following a converted, metric-unit quantity that may misrepresent the precision of a nominal, trade dimension; e.g., "...was built with 5.08- x 10.16-cm (2- x 4-inch) lumber." The following non-SI units are also permitted:

area — hectare (ha) instead of 10^4 m^2;
energy — calorie (cal) instead of Joule (J);
temperature — Celsius (C) instead of Kelvin (K);
time — minute (min), hour (hr), day, etc. instead of seconds (sec) only;
volume — litre (L) instead of dm^3.

Abbreviations, symbols, and acronyms. — Abbreviations and symbols must conform to international recommendations. Authors may consult a recent issue of *Alces* or *The Journal of Wildlife Management* for guidance on abbreviations and symbols. Ratti and Ratti (1988) also provide appendices of standard abbreviations. Extensive lists of recognised abbreviations and symbols can be found in *Scientific style and format: the CBE manual for authors, editors, and publishers* (CBE Style Manual Committee 1994).

Non-standard abbreviations, symbols, and acronyms must be defined (usually in parentheses) when they are first used in the text. Abbreviations, symbols, or acronyms with >1 meaning should be avoided. Do not start sentences with abbreviations, symbols, or acronyms.

Punctuation. — Sentence periods are followed by 2 spaces. Insert a comma before the conjunction in a series of ≥ 3 items (e.g., calves, cows, and bulls). Do not hyphenate prefixes, suffixes, or combining forms unless required to avoid misreading. Closing quotation marks should be placed after periods or commas, but may appear either before or after other punctuation.

Enumerating series of items. — In simple series type Arabic numbers in parentheses. A colon must precede the numbered items unless preceded by a verb or preposition. Numbered items are separated with semi-colons. The last item in a numbered series is preceded by "and". An example of a numbered series is given under "Headings and major sections" (above). When enumerating paragraphs or complexly punctuated series, place the numbers at the left margin, with periods but not parentheses.

Common and scientific names. — Scientific names, italicised and in parentheses, follow the first mention of a common name, except in the title. In scientific names, the first letter of the genus is uppercase, the remainder, and the species name are lower-case. Genus names are abbreviated with their first letter when repeated within a paragraph, provided the meaning cannot be confused with another genus with the same first letter; e.g., "...dominant tree species included red pine (*Pinus resinosa*) and jack pine (*P. banksiana*)." Do not provide subspecies names unless they are important to the study. Do not include the taxonomic author's name. Use "sp." to indicate a single unknown species, or "spp." for plural. Do not give scientific names of domesticated animals or cultivated plants (unless the plant species is endemic, widely escaped from cultivation, or is a variety not adequately described by its common name). Do not capitalise common names, except words that are proper names; e.g., "Alaskan brown bear (*Ursus arctos*)" or "black bear (*Ursus americanus*)."

Spelling. — Authors are responsible for consistency and accuracy in spelling Latin words, especially scientific names, and specialised terms. Either British or American spelling is acceptable, but must be used consistently. Authors should use the "spell-check" feature available in most computer word processors to examine their manuscript for accuracy and consistency of spelling before it is printed and submitted for review.

Citing literature in text. — Authors must ensure that all published literature cited in the text has a corresponding citation in the REFERENCES section. Authors are also responsible for the accuracy of author's names and dates of publications cited in the text. Authors may refer to a recent issue of *Alces* for details of citing literature in the text.

Use the name-and-year system to cite published literature; e.g., Ballard (1995), McLaren and Peterson (1995). Abbreviations may be used if the author is an organisation; e.g., OMNR (1988). Use the first author's last name followed by "*et al.*", if there are ≥3 authors; e.g., Stephenson *et al.* (1995). For citations bound by parentheses, do not separate the author and date by a comma; e.g., (Ballard 1995). Use commas to separate a series of citations given in parentheses and put these in chronological order; e.g., (Edenius 1994, Ballard 1995). If citations in a series have the same year, use alphabetical order within chronological order; e.g., (Edenius 1994, Hindelang and Peterson 1994, Wilton *et al.* 1994, Ballard 1995, Wilton 1995). For citations in a series with >1 reference to the same author(s) in ≥ 2 years, give the name(s) once, separate the years with a comma, and separate the citations with semicolons; e.g., (Ballard 1994, 1995; Edenius 1994; Belant 1995; McLaren and Peterson 1995). Use letters (a, b, c, etc.) to distinguish multiple citations of the same author(s) in the same year; e.g., (Ballard 1994, 1995; Van Dyke 1995; Van

Dyke *et al.* 1995a, b). In the case of direct quotations, close paraphrases, or lengthy publications, provide the author(s) and year, then insert a colon and give the page number(s); e.g., Timmermann and Buss (1995: 4) or (Van Dyke *et al.* 1995: 95-98). [Note that the citations in this paragraph were drawn from previous issues of *Alces* for the purpose of providing examples and are not listed in the REFERENCES section of this paper.]

Documents catalogued in major libraries may be cited as published literature, including theses and dissertations, symposia proceedings, and government reports. Unpublished information or personal communications should be avoided, but if they are used, provide the name and affiliation of the source, then indicate the nature of the citation; e.g., (H. R. Timmermann, Ont. Min. Nat. Res., *pers. comm.*) or (M. W. Lankester, Lakehead Univ., *unpubl. data*). Similarly, information obtained via the Internet should provide the website name and address; e.g., (M. W. Lankester, *Alces* Home Page, *http://www.lakeheadu.ca/~alceswww/alces.html*). Do not provide citations for these sources in the REFERENCES section. Articles "submitted" or "in preparation" should be cited in the text only and referred to as unpublished information. Manuscripts accepted for publication (i.e., "in press") should only be referred to when absolutely essential, and are cited as if they were already published, using the anticipated publication year. If the date is not known, replace the year with "*in press*"; e.g., (Rodgers *et al.*, *in press*). Authors must be prepared to provide evidence that papers cited as "in press" have been accepted for publication.

Reference Styles

Authors are responsible for the accuracy of all information given in the REFERENCES section. References must be checked with original articles and each one must be referred to in the text. They should be listed in alphabetical order according to the author's surname(s). For multiple citations with the same author(s), the sequence is chronological.. References in a given year with the same author(s), must be distinguished by lower-case letters (a, b, c, etc.). Author's names and initials are typed in upper-case letters. Initials are separated by a single space. If the author is an agency, the full name is preceded by the abbreviation used in the text citation within parentheses. For 2 authors, separate their names with "and" (in lower-case letters). If there are ≥ 3 authors, precede the last author's name with ", and" (in lower-case letters). Do not indent the second and subsequent lines of reference citations. Where multiple references with the same author(s) are used, replace the author's name(s) with a solid line of 5 characters, after the first citation.

Except for book or thesis titles and 1-word journal names (e.g., *Ecology*), abbreviations should be used wherever possible in literature citations. Authors should consult a recent issue of *Alces* or *The Journal of Wildlife Management* for guidance on abbreviations used in literature citations. Abbreviations for names of publications commonly cited in *Alces* are given in Table 1. Ratti and Ratti (1988) provide an appendix of abbreviations used for titles of publications. If in doubt, authors should write the name of the publication in full. Titles and inclusive page numbers are required in references to papers in periodicals and books. Citations of manuscripts accepted for publication (i.e., "in press") are formatted as if they were already published, but "*In Press*" should be typed after the volume number or at the end of the citation. If the anticipated date of publication is not known, replace the year with "*In Press*". If a non-refereed report or other document with limited circu-

Table 1. Abbreviations for names of journals and meeting publications commonly cited in *Alces*.

Publication	Abbreviation
Alces Supplement	Alces Suppl.
Canadian Journal of Botany	Can. J. Bot.
Canadian Journal of Forest Research	Can. J. For. Res.
Canadian Journal of Zoology	Can. J. Zool.
Ecological Monographs	Ecol. Monogr.
Forestry Chronicle	For. Chron.
Journal of Forestry	J. For.
Journal of Mammalogy	J. Mammal.
Journal of Range Management	J. Range Manage.
Journal of Wildlife Diseases	J. Wildl. Diseases
Le Naturaliste Canadien	Naturaliste can.
Proceedings of the International Union of Game Biologists	Proc. Int. Union Game Biol.
Proceedings of the North American Moose Conference and Workshop	Proc. N. Am. Moose Conf. Workshop
The Canadian Field-Naturalist	Can. Field-Nat.
The Journal of Animal Ecology	J. Anim. Ecol.
The Journal of Applied Ecology	J. Appl. Ecol.
The Journal of Wildlife Management	J. Wildl. Manage.
Swedish Wildlife Research Supplement	Swedish Wildl. Res. Suppl.
Transactions of the North American Wildlife and Natural Resources Conference	Trans. N. Am. Wildl. Nat. Resour. Conf.
Wildlife Monographs	Wildl. Monogr.
Wildlife Society Bulletin	Wildl. Soc. Bull.

Note: A number of journals commonly cited in *Alces* have 1-word names that are not abbreviated (e.g., *Ecology*), so they are not listed in this table.

lation is cited in the text, the reference should include an address where it may be obtained. Examples of reference styles for the most common literature citations in *Alces* are given below.

Journal articles. — General format;

RISENHOOVER, K. L. 1986. Winter activity patterns of moose in interior Alaska. J. Wildl. Manage. 50:727-734.

Note: abbreviations for names of journals commonly cited in *Alces* are given in Table 1.

Journal articles. — In press, year and volume known;

LANGVATN, R., S. D. ALBON, T. BURKEY, and T. H. CLUTTON-BROCK. 1995. Climate, plant phenology and variation in age of first reproduction in a temperate herbivore. J. Anim. Ecol. 64: *In Press*.

Journal articles. — In press, year and volume not known;

RODGERS, A. R., M. W. LANKESTER, and H. R. TIMMERMANN. *In Press*.

Manuscript guidelines for contributors to *Alces*. Alces.

Book. — General format;

WHITE, G. C., and R. A. GARROTT. 1990. Analysis of wildlife radio-tracking data. Academic Press, Inc., San Diego, CA. 383 pp.

Book. — More than 1 edition;

ZAR, J. H. 1984. Biostatistical analysis. Second ed. Prentice-Hall, Inc., Englewood Cliffs, NJ. 718 pp.

Book. — More than 1 volume;

HALL, E. R. 1981. The mammals of North America. Vol. 1. John Wiley & Sons, New York, NY. 600 pp.

Book. — Editor as author;

WELLS, D. E., editor. 1986. Guide to GPS positioning. Can. GPS Assoc., Fredericton, NB. 567 pp.

Chapter in book. — General format;

FRANZMANN, A. W., and C. C. SCHWARTZ. 1983. Management of North American moose populations. Pages 517-522 *in* C. M. Wemmer (ed.) Biology and management of the Cervidae. Smithsonian Institution Press, Washington, DC.

Note: total page numbers are not given.

Symposia and conference proceedings. — Complete volume;

CRISTALLI, C., C. J. AMLANER, JR., and M. R. NEUMAN, editors. 1995. Biotelemetry XIII. Proc. Thirteenth Int. Symp. Biotelemetry, Williamsburg, VA, March 26-31, 1995. 436 pp.

Note: the place and dates of the meeting must be provided. Abbreviate words like Proceedings (Proc.), Symposium (Symp.), and Transactions (Trans.). Abbreviations for meeting publications commonly cited in *Alces* are given in Table 1.

Symposia and conference proceedings. — Individual article;

RODGERS, A. R., R. S. REMPEL, and K. F. ABRAHAM. 1995. Field trials of a new GPS-based telemetry system. Pages 173-178 *in* C. Cristalli, C. J. Amlaner, Jr., and M. R. Neuman (eds.) Biotelemetry XIII. Proc. Thirteenth Int. Symp. Biotelemetry, Williamsburg, VA, March 26-31, 1995.

Note: the place and dates of the meeting must be provided, but total page numbers are not given.

Symposia and conference proceedings. — Part of a numbered series;

LANKESTER, M. W. 1976. A protostrongylid nematode of woodland caribou and its implications in moose management. Proc. N. Am. Moose Conf. Workshop. 12:173-190.

Theses. — Master's and Ph.D.;

BALLARD, W. B. 1993. Demographics, movements, and predation rates of wolves in northwest Alaska. Ph.D. Thesis, Univ. Arizona, Tucson. 374 pp.

Note: include the province or state name if it is not part of the institution title.

Government publication. — General format;

BISSET, A. R. 1991. Standards and guidelines for moose population inventory in Ontario. Ont. Min. Nat. Resour., Wildl. Branch, Toronto. 37 pp.

Government publication. — Part of a numbered series;

HAYES, R. D., A. M. BAYER, and D. G. LARSON. 1991. Population dynamics and prey relationships of an exploited and recovering wolf population in the southern Yukon. Yukon Fish and Wildl. Branch, Final Rep. TR-91-1. 67 pp.

Government publication. — Agency as author;

(OMNR) ONTARIO MINISTRY OF NATURAL RESOURCES. 1988. Timber management guidelines for the provision of moose habitat. Ont. Min. Nat. Resour., Toronto, ON. 33 pp.

Note: the abbreviated agency name in parentheses precedes the author name and corresponds to the citation in the text; e.g., cited in the text as OMNR

(1988) or (OMNR 1988).

Multiple citations for the same author(s). — General format;

BALLARD, W. B. 1992. Bear predation on moose: a review of recent North American studies and their management implications. Alces Suppl. 1:162-176.

_______, C. L. GARDNER, and S. D. MILLER. 1980. Influence of predators on summer movements of moose in southcentral Alaska. Proc. N. Am. Moose Conf. Workshop. 16:339-359.

_______, and D. G. LARSEN. 1987. Implications of predator-prey relationships to moose management. Swedish Wildl. Res. Suppl. 1:581-602.

_______, and S. D. MILLER. 1990. Effects of reducing brown bear density on moose calf survival in southcentral Alaska. Alces 26:9-13.

_______, _______, and J. S. WHITMAN. 1990. Brown and black bear predation on moose in southcentral Alaska. Alces 26:1-8.

_______, T. H. SPRAKER, and D. K. P. TAYLOR. 1981. Causes of neonatal moose calf mortality in south-central Alaska. J. Wildl. Manage. 45:335-342.

_______, J. S. WHITMAN, and D. J. REED. 1991. Population dynamics of moose in south-central Alaska. Wildl. Monogr. 114. 49 pp.

FINAL SUBMISSION

After revision, accepted manuscripts must be submitted in hardcopy format (2 copies) and in digital form on 9-cm (3.5-inch) diskette. Diskettes must be clearly labelled with the authors' names. Text should be provided both in a common word-processing format (IBM-compatible; preferably WordPerfect or Word) and as an ASCII file. Identify the word-processing software and version number on the diskette. Authors should check the most recent issue of *Alces* or the website to determine which word-processing software formats are currently accepted. The hardcopies and disk file of the manuscript must be identical. An operator will format the manuscript into the double-column layout seen in recent issues of *Alces*.

For final printing of the journal, all illustrations must be prepared as outlined above (see "Figure captions and illustrations"), of professional graphics quality, and reduced to the actual size appearing in the journal (i.e., 67 or 138 mm wide). This must be done by the author(s). If photo-mechanical transfer (PMT) reductions are done by the journal, the author(s) will be invoiced for the work. Similarly, authors may be charged for half-tone production if several photographs are used. In either case, any originals considered illegible after reduction will be returned and publication of the manuscript may be delayed.

GENERAL COMMENTS

As suggested by Ratti and Ratti (1988), many papers with important data and ideas are not published because of poor writing style. Although editors may be patient and provide helpful suggestions, referees are less tolerant of poor writing. This can lead to unnecessarily negative reviews. Initial reaction to these reviews tends to include thoughts like: "stupid reviewers", "they did not understand", or "they did not read the paper carefully". But then, who's fault is it if the reviewers did not understand the work, and who's responsibility is it to help them understand? If the referee is misled, it means at the very least that the prose is not sufficiently clear. A paper's message should be clear, easily appreciated, and convincing. Manuscripts should be direct and concise. Authors should consult one of the many references available for advice; e.g. *Scientific style and format: the CBE manual for authors, editors, and pub-*

lishers (CBE Style Manual Committee 1994). Ratti and Ratti (1988) provide tables of common expressions with superfluous words and commonly misused words, that can be helpful in writing a paper.

These guidelines place a great deal of responsibility on authors. However, adherence to these guidelines is necessary to ensure consistency and to expedite the publication process of *Alces*. The co-operation of contributors is essential.

ACKNOWLEDGEMENTS

We wish to thank Ed Addison, Warren Ballard, Réhaume Courtois, Vince Crichton, Al Franzmann, Pat Karns, Chuck Schwartz, Linda Siczkar, and Ed Telfer for their comments and suggestions regarding the style and format of *Alces* articles, and earlier drafts of these guidelines.

REFERENCES

CBE STYLE MANUAL COMMITTEE. 1994. Scientific style and format: the CBE manual for authors, editors, and publishers. Sixth ed. Council of Biology Editors, Inc., Chicago, IL. 825 pp.

RATTI, J. T., and L. W. RATTI. 1988. Manuscript guidelines for *The Journal of Wildlife Management*. J. Wildl. Manage. 52 (1, Suppl.). 22 pp.

Revisions to the Manuscript Guidelines for Contributors to *Alces*

- For all References, spell out the names of books, proceedings and journals in full.
- Eliminate the use of all other abbreviations in the References section except for M.Sc., Ph.D., Inc., Ltd., U.S., U.S.A., D.C., and U.K.
- Do not provide the total page numbers of books, theses, or government publications in the References section.
- Use large and small capital letters for author(s) names in the References section (e.g., KARNS, P.D., and V. CRICHTON).
- Where there are two (2) authors of a paper cited in the References section, follow the first author's initials with a comma (see example above).
- If e-mail addresses are provided, include them with the affiliation and mailing address of authors following the title on the first page.
- If not the first author, indicate the corresponding author in a footnote on the first page. Do not italicize "et al.", "unpublished data", "personal communication", or "in press" when citing sources in the text.
- Do not use an apostrophe for plural dates (e.g., use 1970s instead of 1970's) or with acronyms (e.g., use ANOVAs instead of ANOVA's).
- When citing websites in the References, provide the month and year the website was last accessed by the author(s); e.g., Accessed June 2007.

Checklist of Common Errors in Manuscripts Submitted to *Alces*

- For all References, spell out the names of books, proceedings, and journals in full – DO NOT ABBREVIATE.
- References should be in alphabetical order regardless of the number of multiple authors (i.e., use the surname of the first author, then the surname of the second author, then the surname of the third author, and so on) – for multiple citations with the same authors, the sequence is chronological.
- Surnames of authors in the References section should be given in LARGE and SMALL capital letters (in Microsoft Word Choose Format>Font, then check the box next to Small caps in the Effects section of the dialogue box).
- Where there are two (2) authors of a paper cited in the References section, follow the first author's initials with a comma (e.g., KARNS, P.D., and V. CRICHTON).

- Do not provide the total number of pages for books, theses, or government reports in the References section.

- Provide the publisher and place of publication (city and country) for all books theses, and government reports in the References section.

- Authors must ensure that all published literature cited in the text has a corresponding citation with the same year of publication in the References section and that all references listed have been cited in the text.

- Do not italicize "et al.", "unpublished data", "personal communication", or "in press" when citing sources in the text.

- All conjunctions (and, or) in a series of 3 or more items should be preceded by a comma (e.g., calves, cows, and bulls), both in the text and in the References section.

- Standard abbreviations should be followed by commas (i.e., and e.g.,).

- Table columns must be generated with tab settings or a table editor – do not use the space bar. ONLY horizontal lines should be used in Tables. The layout of tables should resemble those in recent issues of *Alces*.

- More than 3 colours or shades of gray used for maps and bar graphs may not be clearly differentiated when printed in black and white – solids (black or white) and patterns (stippling, crosshatching) are better.

- A common font such as Times Roman should be used for ALL text and tables and a sans serif font such as Arial should be used in figures - the same font should be used for ALL figures.

Submissions

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Natural Resources and Environmental Studies Institute
University of Northern British Columbia
E-mail:Roy.Rea@unbc.ca

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