# Altitude, latitude, and climate zone as determinants of mountain hare (*Lepus timidus*) coat colour change

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# Abstract

Local adaptation to annually changing environments has evolved in numerous species. Seasonal coat colour change is an adaptation that has evolved in multiple mammal and bird species occupying areas that experience seasonal snow cover. It has a critical impact on fitness as predation risk may increase when an individual is mismatched against its habitat's background colour. In this paper we investigate the impact of landscape covariates on moult timing in a native winter-adapted herbivore, the mountain hare (*Lepus timidus*), throughout Norway. Data was collected between 2011 and 2019 at 678 camera trap locations deployed across an environmental gradient. Based on this data, we created a Bayesian multinomial logistic regression model that quantified the correlations between landscape covariates and coat colour phenology and analysed among season and year moult timing variation. Our results demonstrate that mountain hare moult timing is strongly correlated with altitude and latitude with hares that live at higher latitudes and altitudes keeping their winter white coats for longer than their conspecifics that inhabit lower latitudes and altitudes. Moult timing was also weakly correlated with climate zone with hares that live in coastal climates keeping their winter white coats for longer than their moult timing has adapted to local environmental conditions throughout Norway.

#### Introduction

For species living in seasonal environments (e.g. from summer to winter or from dry to wet season) local adaptations to annually changing environmental conditions may evolve. Numerous species have evolved to time their life history events to match these changes in local seasonal conditions (Bradshaw and Holzapfel 2007, Williams et al. 2015). To time these phenological events, one reliable "zeitgeber" is daylength or photoperiod (Gwinner 2003, Hofman 2004), either on its own or in combination with other variables, such as temperature (Watson 1963, Jackes and Watson 1975, Larkin et al. 2001) and snow cover (Watson 1963, Flux 1970, Zimova et al. 2014).

Many animal species use photoperiod to time breeding (Goldman 1991, Gwinner 1996b, Dawson et al. 2001, Coppack and Pulido 2004), moulting (Lesher and Kendeigh 1941, Lyman 1943, Bissonnette and Bailey 1944), and migration (Gwinner 1996a), and other life history events. As photoperiod remains constant between years at specific locations, between year variation in local conditions could result in photoperiod timed phenological events being mistimed against the local environment. Fluctuations in environmental variables, such as precipitation (Villellas et al. 2014) and temperature (Ashmore and Janzen 2003, Kreyling et al. 2019), can result in increased within-species phenotypic variation in a variety of plant and animals species when compared to individuals of the same species that live in more stable habitats. Consequently, synchrony in phenological timing of individuals within a population is expected to increase with climate stability.

Animals occupying areas that are seasonally covered by snow live in environments that change from dark in summer to white in winter. As a predator avoidance strategy, at least 21 species (Mills et al. 2018, Zimova et al. 2018) have adapted seasonal changes in colouration of fur and feather, which provides camouflage in both a winter white and summer dark landscapes (Wallace 1879, Cott 1940, Merilaita and Lind 2005). To provide optimal camouflage, the timing of coat colour change should be synchronised with the period of continuous snow cover. Individuals would thus be expected to adapt the timing of their coat colour change to local conditions. Indeed, mismatched timing of coat colour change is linked to range contractions and population declines in several species including snowshoe hares, (Diefenbach et al. 2016, Sultaire et al. 2016), mountain hares (Acevedo et al. 2012, Pedersen et al. 2017), rock ptarmigan (Imperio et al. 2013), and white-tailed ptarmigan (Wang et al. 2002), showing the importance of correct timing. However, snow conditions might not be stable from year to year, and there might be seasonal differences in the predictability of the appearance and disappearance of snow.

There are some suggestions that snow cover might be more stable in spring compared to autumn. Snowshoe hares (*Lepus americanus*) (Zimova et al. 2014) and least weasels (*Mustela nivalis nivalis*) (Atmeh et al. 2018) exhibit limited phenotypic variation in moult timing in parts of their distribution during the spring moult, when transitioning from white to brown, but not during the autumn moult, when transitioning from brown to white. Therefore, the timing of seasonal coat colour change is expected to be more synchronised in spring compared to autumn. This could result in clearer differences in the timing of among years moult timing in the spring compared to the autumn. However, this is the first long-term study over a geographical area large enough to test these predictions.

Mountain hares (Lepus timidus) express seasonal coat colour change in most of their range, except the subspecies of Irish hare (L. t. hibernicus) found in Ireland (Mills et al. 2018). They are a generalist herbivore inhabiting boreal and alpine areas that occupy a wide range of climatic, latitudinal, and altitudinal gradients, experiencing large variations in winter snow cover duration. Coastal areas in the south and southwest of Norway experience relatively short snow cover duration compared to inland areas and areas in the north (Schuler et al. 2006) with coastal areas in the south and south-west receiving as little as one month of snow cover per year (Tallaksen et al. 2018). Additionally, coastal areas experience greater between-year variation in the depth and extent of snow cover than inland areas (www.senorge.no).

Here, we provide the first quantitative study of variation in mountain hare moult timing with nine years of data using 678 camera locations along an extensive geographic gradient in Norway. We studied 1) how the timing of moult varied with local geographical conditions and 2) how the timing of moult varied among years and seasons, utilising camera trap data in a Bayesian multinomial logistic regression model framework. Snowshoe hares that live at lower altitudes and latitudes displayed winter coats for a longer time compared to their low latitude (Grange 1932, but see Zimova et al. 2019) and altitude conspecifics (Holmgren et al. 2001, Nowak et al. 2020, Zimova et al. 2020b). Also, increased snow cover in continental areas is likely to result in hares living in these areas keeping their winter coats for longer than hares in coastal areas. Therefore, we used altitude, latitude, and climatic zone, distinguishing between coastal and continental climates, as indicators of local geographical conditions for our first aim. For our second aim, we predicted that moult timing would be more synchronised among individuals in spring compared to autumn, based on previous studies on snowshoe hares (Mills et al. 2013, Zimova et al. 2014). Furthermore, we predict larger among year variation in the timing of moult in spring compared to autumn.

# Methods

# Data collection

Mountain hares predominately inhabit boreal and alpine habitats. They have a circumpolar distribution spread across Europe and Asia from Britain and Ireland in the west to Japan in the east (Angerbjorn and Flux 1995). They are native to Norway and are found throughout the country, with their distribution ranging

from sea level to around 1,600 m, which is above the tree line. Population size within Scandinavia is thought to be decreasing (Pedersen and Pedersen. 2012, Elmhagen et al. 2015, Pedersen et al. 2017) resulting in the species being classified as "near threatened" in the 2015 Norwegian Red List (Henriksen and Hilmo. 2015).

We utilized images from camera traps that were deployed by the SCANDCAM project (viltkamera.nina.no), originally designed to monitor Eurasian lynx (Lynx lynx) (Hofmeester et al. 2021). Camera traps were deployed in multiple study areas in an extensive grid with approximately one camera per 50 km<sup>2</sup> grid cell (Figure 1). For this study, we selected all mountain hare records from the period between 25th November 2010 and 25th June 2019. Images containing mountain hares were recorded at 678 locations from 2010-2019 spanning a latitudinal gradient from 58°N to 69° N and altitudes from 0 to 841 m a.s.l. in Norway (Figure 1). To reduce pseudo-replication, we discarded observations recorded within 60 minutes of the previous observation. Mountain hares and invasive European hares (Lepus europaeus), which are also present in south eastern Norway (Viken County), were differentiated using the species descriptions contained in Smith et al (2018). When mountain hares were identified, we classified moulting stage in three categories (Zimova et al. 2020a) estimating the proportion of the hares' coat (excluding the long white belly) which was white. 1) Hares with [?]90% white fur were classified as "white", 2) hares with [?]10% white fur were classified as "brown", and 3) all other hares were classified as "moulting". All images were accessed on viltkamera.nina.no and were visually classified by one of two observers, and quality controlled whenever the observer was uncertain of how to classify the images.



Figure 1. The location of camera trap sites that recorded a mountain hare observation during 2010-2019 (black circles). The camera traps were deployed across an environmental gradient within Norway by the SCANDCAM project, with latitudes varying between 58°N and 69° N.

# Covariates

We divided the year into two seasons, "spring" and "autumn". Spring was defined as ordinal day 1 (1<sup>st</sup> January) to ordinal day 212 (1<sup>st</sup> August in non-leap years), and autumn for the rest of the year. Ordinal day 212 was chosen as all mountain hares had moulted to their summer brown coats by this date and had not started moulting back to winter white. Altitude and latitude were extracted based on camera trap positions. We obtained altitude from a digital elevation model (DEM) with 50 m<sup>2</sup> resolution (Kartkatalogen

2007) (Suppl. 2) using the *raster* package's (Hijmans 2022) extract function. We obtained climate zone as a continuous variable with a resolution of 1 km<sup>2</sup> from Bakkestuen et al (2008) (Suppl. 1). We converted climate zone vector data to a raster using the *fasterize* (version 1.0.4) package (Ross 2020). Bakkestuen et al (2008) mapped climate zones by conducting principal component analysis (PCA) using terrain data, climatic data, hydrological data, and geological data. A positive PCA value indicates a continental climate whereas a negative value indicates a coastal climate.

# Data analysis

We used multinomial logistic regression to estimate the probability of a hare being in moult category i (white, moulting, or brown) on each ordinal day d. We included year k specific intercepts to test if moult timing varied between years. The model used the following equation:

$$p(y=i) = \frac{e^{\alpha_{ik}+\beta_{1i}\times d+\beta_{2i}\times a_j+\beta_{3i}\times l_j+\beta_{4i}\times c_j+s_{ij}}}{1+\sum_{i=1}^{i-1}e^{\alpha_i+\beta_{1i}\times d+\beta_{2i}\times a_j+\beta_{3i}\times l_j+\beta_{4i}\times c_j+s_{ij}}}$$

Where d is ordinal day, and  $a_j$ ,  $l_j$ , and  $c_j$ , respectively, are the altitude, latitude, and climate zone at camera site j (as adapted from Zimova et al 2019 and 2020b). Parameters $\beta_{1-4\theta}$  represent the slopes for the different covariates. We included a category i and year k specific intercept  $a_{i\kappa}$  as well as a site-specific random intercept  $s_{ij}$  to correct for multiple observations per camera site. The brown category was set to 0 in both spring and autumn models to provide a baseline for comparison with moulting and white categories.

We implemented the multinomial logistic regression models in a Bayesian framework using JAGS (Denwood 2016) called from R V4.1.3 (R Core Team 2022) with the *jagsUI* package (version 1.5.2) (Kellner 2021). We standardized altitude, latitude, and climate zone (mean = 0, SD = 1) before running the models. Ordinal day was included as an explanatory covariate to enable estimation of the probability of a hare being white, brown, or moulting between coats on specific days of the year. We checked for collinearity between the covariates using both the variance inflation factor (VIF) and Pearson correlation coefficient. For every covariate combination the Pearson values were below 0.6 (Suppl 6) and VIF values were below 2.0 (Suppl 7).

We used uninformative, normally distributed priors with a mean of 0 and precision of 0.01 for all slopes and the year k specific intercepts. For the site s random intercept, we used a mean of 0 and a standard deviation defined as a vague prior with a uniform distribution between 0 and 100. We ran the model with three chains all thinned by 100 for 120,000 iterations, with a burn-in of 60,000 iterations. We confirmed model convergence using traceplots and the Gelman-Rubin convergence statistic (R-hat) (Brooks and Gelman 1998) with all variables used in the final models having R-hat values of 1.10 or less. Additional models in which the dataset was subset to only include cameras located south of 61° North were used to test if model performance was affected by camera trap placement north of this latitude. The results were consistent with those obtained using the full dataset indicating that camera placement north of 61° did not affect model performance. We produced all figures using the ggplot2(Wickham 2016), raster (Hijmans 2022), and cowplot (Wilke 2020) packages.

#### Results

Between 2010 and 2019 a total of 9,981 mountain hare observations were obtained at 678 camera trap locations (Figure 1 and Suppl 4). Only two observations were recorded in 2010, which we discarded due to the small sample size. Of the remaining observations, 7,454 were recorded in "spring" and 2,525 were recorded in "autumn". The number of camera traps deployed across Norway increased throughout the study period, leading to an increase in the number of observations obtained in each year (see Suppl 3 for location of traps that recorded observations in each year). Camera traps that recorded mountain hare observations were located between altitudes of 0 and 841 m.a.s.l., latitudes were between 58° N and 69° N, and climate zone PCA values were between -2.68 (coastal climate) and 2.86 (continental climate). The results from our multinomial logistic regression model indicate that all three explanatory covariates, altitude, latitude, and climate zone, correlated with moult timing in spring and autumn. We found strong evidence for hares keeping their winter white coats for a longer duration at increased altitude and latitude (Figures 2.a and b.). The probability of being white increased with altitude in spring ( $\beta_{2,\omega\eta\eta\tau\epsilon} = 1.492, 95\%$  credible interval (CI) = 1.309 to 1.673; Figure 2.a) and in autumn ( $\beta_{2,\omega\eta\eta\tau\epsilon} = 0.870, 95\%$  CI = 0.639 to 1.117; Figure 2.a). Similarly, the probability of being white increased with latitude in spring ( $\beta_{3,\omega\eta\eta\tau\epsilon} = 2.472, 95\%$  CI = 2.265 to 2.672; Figure 2.b) and in autumn ( $\beta_{3,\omega\eta\eta\tau\epsilon} = 0.642, 95\%$  CI = 0.443 to 0.844; Figure 2.b). Climate zone had the smallest effect size in both spring and autumn. The probability of being white decreased with an increasingly inland climate (increasing PCS values) in both spring ( $\beta_{4,\omega\eta\eta\tau\epsilon} = -0.335, 95\%$  CI - 0.510 to - 0.163; Figure 2.c) and autumn ( $\beta_{4,\omega\eta\eta\tau\epsilon} = -0.287, 95\%$  CI - 0.525 to - 0.053; Figure 2.c).

The ordinal day where the probability of being white is 50 % occurred 27 days earlier in spring and 23 days later in autumn for hares at sea level compared to 700 m a.s.l. (Figure 2 a). At 59° N the ordinal day where the probability of being white is 50% occurred 27 days earlier in spring and from brown to white 14 days later in autumn compared to hares at 65° N (Figure 2.b). Hares living in inland climates moulted 9 days earlier in spring and 11 days later in autumn (Figure 2. c).

Mountain hare moult timing varied across mainland Norway (Figure 3). Starting in mid-winter moving into spring, there was a travelling wave of moulting moving from lower to higher altitudes and latitudes (Suppl 10). The opposite effect was observed in autumn. The altitudinal and latitudinal moult timing gradients show that hares that inhabit mountainous areas and the north of Norway kept their winter white coats for longer than their conspecifics that inhabit low altitude and latitude areas. The model output, which represents all of Norway, indicates that mountain hares in coastal areas moult later in spring and earlier in autumn (Figure 2.c.). The prediction maps show that hares in southern Norway's coastal areas Norway moult earlier in spring and later in autumn (Figure 3.a and 3.f.), indicating that the effect of latitude is stronger than the effect of climate zone. This is consistent with the climate zone effect sizes being smaller than those of altitude and latitude. Predictions for areas outside of camera trap locations (Figure 1) should be interpreted with care as these results are extrapolated.



Figure 2. Timing of spring and autumn moult at different altitudes (a), latitudes (b), and climate zones (c).

Solid lines represent the predicted probability of being white and shaded areas indicate the 95% credible intervals. Figures use the mean of all intercepts included in the final models.



Figure 3. Prediction maps with a resolution of  $1 \ge 1 \text{ km}^2$  giving the probability of mountain hares being white across Norway on ordinal days 105, 135, 165, 255, 285, and 315. The probability of being white was predicted using the model output and the environmental covariates contained in every cell.

Timing of spring and autumn moults varied slightly between years (Figure 4). From 2013 onwards the 95% CIs are consistently narrower in spring than in autumn, which probably results from increased sample sizes in spring (Suppl 4). For the spring intercepts, multiple years have non-overlapping CIs for 90% white, which signifies the start of spring moulting, and 90% brown, which signifies the end of spring moulting. For example, 2013 does not overlap with 2014 and 2017 does not overlap with 2018. For the autumn intercepts, the brown CIs, signifying the start of autumn moulting, overlapped in most years. The CIs for 90% white, signifying the end of autumn moulting, overlapped in all years. The time taken for moulting in spring to finish, represented by the number of days between 90% of hares being white and 90% of hares being brown, ranged between 46 days in 2019 and 64 days in 2013 and 2018 (Suppl 9). The time taken for moulting to occur in autumn ranged between 38 days in 2011 and 72 days 2013. In autumn, both the shortest and longest time taken were in years with limited sample sizes (Suppl 4). Therefore, these results should be viewed with caution.



Figure 4. Between year intercepts with 95% CI for spring and autumn at mean latitude, altitude, and climatic zone. Grey dots with 95% CI represent the mean ordinal day on which 90% of hares are white. Brown dots with 95% CI represent the mean ordinal day on which 90% of hares are brown. The supplemental information contains the sample sizes (Suppl 4), intercept beta values (Suppl 5), and the number of days between the midpoints (Suppl 9).

# Discussion

We used camera trap by-catch observations to provide the first quantitative assessment of how large-scale environmental variables correlate with mountain hare moult timing. As predicted, hares at higher altitudes and latitudes moulted later in spring and earlier in autumn, keeping their winter white coats for longer, compared to their lowland and low altitude conspecifics. Contrary to our prediction, we found support for a later spring moult and earlier autumn moult in areas characterised by coastal climates, rather than inland climates, resulting in hares that live in areas with coastal climates keeping their winter white coats for longer than their inland conspecifics.

The unexpected correlation between climate zone and moult timing (Figure 2.c.) could result from variation explained by climate zone also being partially explained by altitude (Pearson correlation coefficient > 0.5 in both seasons) and latitude (Pearson correlation coefficient < -0.3 in both seasons) (Suppl 6). Additionally, all camera traps from 63° North are close to the coast which may confound results. However, in southern Norway there is a coastal to continental moult timing gradient shown in the prediction maps (Figure 3.a. and 3.f.). Furthermore, it is likely that there will be increased variability in moult timing in coastal climates as there is increased among year variation in snow cover and duration compared to continental climates (senorge.no).

Both altitude (Figure 2.a) and latitude (Figure 2.b) had the predicted correlation with moult timing. Mountain hares that inhabit areas characterised by higher altitude and latitude moulted later in the spring and earlier in the autumn, keeping their winter white coats longer, likely due to an expectation of longer snow cover duration. These results are consistent with previous studies of other mountain hare populations and other hare species, which found that increased elevation correlated with mountain hares keeping their winter coats for longer (Watson 1963) and increased latitude correlated with snowshoe hares keeping their winter white coats for longer (Grange 1932). However, a more recent study on snowshoe hares found no evidence of moult timing variation across a latitudinal gradient in autumn and, in spring, hares that live at high latitudes became brown earlier than those at lower latitudes (Zimova et al. 2019). The correlations between moult timing and altitude and latitude indicates that mountain hare populations have adapted to local conditions, which suggests that gene flow between populations is insufficient to dilute local adaptations. This is particularly true for altitude as this variable can change significantly over a short geographic distance. The non-overlapping CIs between some years in the spring moult (Figure 4) indicate that there is some between year phenotypic variation. However, the between year difference in moult timing is small, which is consistent with photoperiod rather than climate being the main driver of mountain hare moult timing (reviewed in Zimova et al. 2018). This is consistent with similar studies conducted on snowshoe hares (Mills et al. 2013, Zimova et al. 2014) and least weasels (Atmeh et al. 2018), which found evidence of between year phenotypic variation in spring, but not in autumn. The limited moult timing variation may reduce fitness as an inability to change moulting patterns in response to among year variation in snow extent and duration will increase camouflage mismatch and, consequently, decrease survival probability (Zimova et al. 2016). Behavioural responses to mismatch are possible, micro-habitat patch selection, changed diurnal activity patterns, or manually removing winter fur during the spring moult. However, there is currently no evidence of snowshoe hares modifying their behaviour in response to being mismatched (Zimova et al. 2014).

Moult timing variation could result from population level phenotypic variation, individual level phenotypic plasticity, or a combination of both factors. As our methodology did not facilitate monitoring specific individuals, we could not disentangle the relative importance of population and individual level variation. Observations were obtained at specific locations in multiple years (Suppl 8). This makes it likely that some individuals were recorded in multiple years, increasing the probability of individual phenotypic plasticity influencing results.

As the camera traps were deployed to maximise the probability of detecting lynx their locations within the surveyed area were not randomised and some areas of Norway were not monitored. Additionally, we obtained three times as many observations in spring compared to autumn (Suppl 4), which is probably caused by increased hare activity patterns during the mating season (Pettigrew et al. 2021) and the spring dataset containing observations for 58 more days. This resulted in the intercept CIs (Figure 4) being larger in autumn than in spring. Despite these issues, the prediction maps (Figure 3 and Suppl 10) indicate that the model produces accurate results.

Understanding the role that environmental characteristics have on moult timing is vital when assessing the impact that climate change may have on species that express a seasonal coat colour change. Our study sites span 1,300 km and 11 latitudinal degrees, from sea level to 841 m.a.s.l. making this is the first study that investigates moult phenology over a large, continuous climatic gradient spanning three biomes (temperate forest, boreal forest, and alpine tundra). Analysing the correlation between the explanatory variables and mountain hare moult timing will enable us to predict how the species will react to climate change induced reductions in snow cover extent and duration. We plan to investigate this issue in a future paper.

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## Data Accessibility

Dataset used for analysis including phenotypic and environmental data and the location where the observations were collected: Figshare, DOI: 10.6084/m9.figshare.22560340

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Supplemental information



Supp 1. Climatic zones across Norway obtained from Bakkestuen et al (2008). Negative values indicate an oceanic climate whereas positive values indicate a continental climate. Values were obtained via principle component analysis (PCA).



Supp 2. Digital elevation model (Kartkatalogen 2007) with a resolution of 50  $m^2$  giving the altitude across Norway. The altitude of the camera traps used in this study varies between 0 m and 841 m above sea level.







Supp 3. Location of the camera traps that recorded at least one observation in each year. The locations are laid over the DEM. Suppl 4. The number of samples recorded by camera traps in spring and autumn from 2010 to 2019. The number of samples recorded increased as the study progressed due to an increase in the number of traps deployed.

Year	Spring	Autumn
2010	NA	2

Year	Spring	Autumn
2011	40	36
2012	113	80
2013	258	23
2014	308	165
2015	859	204
2016	602	358
2017	1,517	644
2018	2,035	1,027
2019	1,738	NA

Suppl 5. The beta intercepts taken from our Bayesian multinomial logistic regression model. They illustrate the between season and year variation in moult timing.

Year	Spring (95% CI)	Autumn (95% CI)
2011	20.932 (15.809 to 29.746)	-44.525 (-48.253 to -40.601)
2012	21.438 (19.727 to 23.146)	-43.931 (-47.367 to -40.340)
2013	27.432 (25.804 to 29.129)	-43.677 (-47.693 to -39.776)
2014	23.819 (22.364  to  25.148)	-43.201 (-46.692 to -39.672)
2015	23.923 (22.530  to  25.338)	-43.494 (-46.964 to -39.944)
2016	24.338 (22.925  to  25.727)	-44.456 (-47.803 to -40.869)
2017	$22.761 \ (21.478 \text{ to } 24.114)$	-44.174 (-47.477 to -40.675)
2018	26.066 (24.622  to  27.529)	-44.424 (-47.751 to -40.946)
2019	24.942 (23.549 to 26.324)	NA

Suppl 6. Pearson's correlation coefficient (3 SF) between altitude, latitude and climate zone in spring and autumn. All years and camera sites were used for the calculations. The datasets were subset so that only one observation per site was used for the calculation.

Spring	Spring	Spring	Autumn	Autumn	A
Altitude * latitude -0.0295	Altitude * climate zone 0.530	Latitude * climate zone -0.362	Altitude * latitude -0.0649	Altitude * climate zone 0.548	La -0

Suppl 7. Variance inflation factor (VIF) (3 SF) between elevation, latitude and climate zone in spring and autumn. All years and camera sites were used for the calculations. The datasets were subset so that only one observation per site was used for the calculation.

Spring	Spring	Spring	Autumn	Autumn	Autumn
Altitude	Latitude	Climate zone	Altitude	Latitude	Climate zone
1.47	1.20	1.69	1.45	1.12	1.60

Suppl 8. The number of years that observations were obtained in for every camera trap location that obtained a mountain hare observation.

Number of camera trap locations	Number of years samples were obtained in
304	1
180	2
116	3
39	4
30	5
4	6
1	7
2	8
2	9

Suppl 9. The ordinal days in which moult was initiated and finished in spring and autumn. In spring, moult initiation was defined as the day on which less than 90% of the hare was white and moult end was defined as the day on which less than 90% of the hare was white. In autumn, moult initiation was defined as the day on which less than 90% of the hare was brown and moult end was defined as the day on which less than 90% of the hare was brown and moult end was defined as the day on which less than 90% of the hare was brown.

Year	Ordinal day when spring moult started	Ordinal day when spring moult finished	Days taken to moult in spring
2011	74	124	50
2012	75	135	60
2013	101	165	64
2014	88	142	54
2015	90	141	51
2016	92	143	51
2017	84	136	52
2018	100	150	50
2019	96	142	46

# Hosted file

image16.gif available at https://authorea.com/users/603769/articles/633959-altitude-latitudeand-climate-zone-as-determinants-of-mountain-hare-lepus-timidus-coat-colour-change

Suppl 10. Prediction map animation with a resolution of  $1 \ge 1 \text{ km}^2$  giving the probability of mountain hares being white across Norway on every day of the year. The probability of being white was predicted using the environmental covariates contained in each cell and the model output.