GROUSE NEWS

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From the Editors

It has now been nearly five years since many of us have seen each other in person. The long-time grousers are likely a little more grey, and little more forgetful, and little more cynical. Over those years, a new generation of grouse researchers and enthusiasts has emerged, and while we might recognize names, the opportunity to again meet in person and discuss grouse or other matters over dinner or coffee or beer will be greatly welcomed, and even old colleagues might again become close friends. Especially for many of the new generation, the International Grouse Symposium will likely be the first time they have been able to put a face to a name, and for the long-timers, we welcome the opportunity to meet those that will carry things forward for the future decades. As representatives of the long-timers, we hope we are leaving a legacy as well as ample numbers of the wild birds we love so dearly. At the last International Grouse Symposium, Poland offered to host the IGS in 2021, and the attendees in Utah enthusiastically accepted their proposal. With both great respect and sadness, several of the 2018 attendees are no longer with us. Who could have predicted in 2018 the chaos that would prevent us from coming together in 2021, and then again in 2022? We are proud, at least, that we have been able to maintain some semblance of communication through this venue, and despite the obstacles, the number of members and subscribers to Grouse News continues to rise, even though some of the species we study or love have continued to decline. The conservation efforts and the science goes on and technology improves, as reflected in articles in this issue on stable isotope analysis and the use of remote sensing equipment. Still, there is much more research happening across the continents than what is reflected here, and we continue to encourage everyone to consider submitting short note, updates, abstracts and full-length articles that would be of interest to other grouse researchers.

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From the Chair

I was fortunate to spend the last three weeks of April counting, capturing, and translocating sharp-tailed grouse from British Columbia to Washington. I love fieldwork and the opportunity to spend time in remote areas with other people that also care deeply about grouse. It was a reminder of how much we lost during the pandemic. There were few distractions (other than grouse), lots of opportunities to talk, and no masks. These are some of the reasons why I encourage you to consider attending the International Grouse Symposium (IGS) on the Campus of the University of Białystok, in Poland, 11–17 September 2022 (https://igs2022.uwb.edu.pl/). Please note that the deadline for abstracts is the end of May. Due to delays from COVID and war, it has been 5 years since the IGS has been held. Five years is too long of a delay for a meeting that is normally held every three years. It is essential that we do our best to resume a normal 3-year schedule. Part of this resumption of 'normal' is for you to consider attending the symposium in Poland. The hosts have done a great job organizing this meeting, under tremendous difficulties, and I am certain they would love to see you at the University of Białystok. Regardless of your decision, please consider hosting the next meeting in 2026. The problems faced by many of the World's grouse species are becoming more critical every year and conferences like this offer an excellent opportunity to exchange information and ideas. I hope to see you in Poland!

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NEWS FROM GALLIFORMES SG

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NEWS FROM GROUSE GROUP

CONSERVATION NEWS

Sage Grouse: Icon of the West.

Greater Sage-Grouse *Centrocercus urophasianus* are the largest grouse in North America and are symbols of the unique and diverse habitat of the American West. These upland birds make their home in the sagebrush, as do 350 other species and thousands of ranchers who rely on Western rangelands for their agricultural operations. The USDA's Natural Resources Conservation Service launched the Sage Grouse Initiative in 2010 to proactively conserve America's western rangelands, wildlife, and rural way of life.

Sage grouse are found in open spaces with hot, dry summers and cold winters that are dominated by sagebrush, native grasses, and wildflowers. Sagebrush leaves year-round, augmented seasonally by other soft plant leaves, stems, and buds as well as insects. Since they lack the well-developed gizzard that many birds have, sage grouse don't eat seeds.

Working Lands for Wildlife (WLFW) is the USDA Natural Resources Conservation Service's (NRCS) win-win approach for conserving America's working lands to benefit people, wildlife, and rural communities. WLFW provides technical and financial assistance to landowners who voluntarily implement conservation actions that reduce threats facing both agricultural land and wildlife populations. More than 8,800 producers in the United States have teamed up under WLFW and conserved more than 10.4 million acres.

For more info see https://storymaps.arcgis.com/stories/8333a6b6e513407fafa2eb3f52ee9c50.

RESEARCH REPORTS

Seasonal changes of stable isotope signals in the primary feathers of plains sharp-tailed grouse

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Abstract

Stable isotopes of a consumer organism can be used to estimate the proportional utilization of food items that have different isotopic signals to estimate changes in diet over time. Using stable isotopes as biotracers has become a useful tool for investigating trophic dynamics in ecosystems. Recent advances in the theory of stable isotope dynamics and food web modeling have extended the utility of natural variations in stable isotope abundance. However, as a growing field, some potentially useful approaches to using stable isotopes remain untested. Here, we used stable isotopes of nitrogen (δ^{15}N) and carbon (δ^{13}C) to validate their utility in examining the feeding relationships of plains sharp-tailed grouse (*Tympanuchus phasianellus jamesi*; hereafter sharp-tailed grouse) in southern Alberta, Canada. Sharp-tailed grouse are known to consume mostly plants and opportunistically utilize insects and spiders as a high protein food source between May and October. Primary feathers obtained from hunter harvested grouse were analysed and used to estimate diet proportions of vegetation and arthropods during this time frame. Stable isotope measurements of primary feathers were able to show seasonal changes in sharp-tailed grouse diet. Our results indicated that sharp-tailed grouse may primarily utilize nutrients obtained from insect prey (mainly grasshoppers) for feather synthesis during molt, and that the isotope signals found in primary feathers may be a result of isotopic routing. Stable isotope data also reflected known differences among adult female and male, and juvenile grouse feeding ecology. However, model uncertainty existed due to isotopic similarity of some plant and animal food sources.

Introduction

Plains sharp-tailed grouse (*Tympanuchus phasianellus*; hereafter sharp-tailed grouse) are an important indicator species on prairie landscapes in North America and have declined in many parts of their range in recent years (Connelly et al. 1998). Grouse population declines have been attributed to habitat loss, degradation, and fragmentation (Manzer and Hannon 2007), grazing management of domestic livestock (Mcnew et al. 2017), and climate change (Forbey et al. 2014). Recent trends in grouse research have seen a decrease in the number of studies examining diet in favor of new areas of focus in conservation made possible with technological advances, such as genetics and landscape-scale ecology (Moss et al. 2010). Information about feeding relationships may help in identifying changes to grouse ecology, and potential limiting factors as climate change alter plant and arthropod phenology and biodiversity, and consequently affect food availability (Walther et al. 2002, Booth et al. 2012). Arthropod prey are an important high protein food source for many birds, including grouse (Sullins et al. 2018), and some studies indicate alarming rates of decline of both arthropods and birds around the world (Nebel et al. 2010, Hallmann et al. 2017).

Conventional diet studies on sharp-tailed grouse (*T. p. jamesi*) have detailed the types of food items grouse utilize at different times of the year from esophageal crop contents and fecal analysis (Aldous 1943, Kobriger 1965, Renhowe 1968, Sisson 1976, Mitchell and Riegert 1994), however, these types of studies have several limitations (Votier et al. 2003). Soft food items are often underestimated as they are quickly broken down and become unrecognizable (Sullins et al. 2018), tracking diet over large spatial or temporal scales may be difficult, and esophageal crop contents only provide a snapshot of the animals' diet at the time of collection (Layman et al. 2015), which may be weather dependent (Erikstad and Spidsø 1982). As an alternative to conventional diet studies, stable isotopes have shown great promise in elucidating aspects of food web ecology and is a widely accepted technique for diet reconstruction and food web analysis. Nitrogen (N) and carbon (C) are the most common elements used in food web analysis as δ15N generally shows a stepwise increase with trophic level, and δ13C can be used to trace carbon sourcing from isotopically distinct sources (Fry et al. 1978, Post 2002, Layman et al. 2012). Stable isotopes have been used to estimate diet proportions in greater sage grouse (*Centrocercus urophasianus*) chicks (Blomberg et al. 2013) and Attwater's prairie chicken (*Tympanuchus cupido attwateri*; Torres-Poche 2017), and each study has revealed important information about the trophic ecology of grouse. Torres-Poche (2017) found that historic prairie chicken feathers from museum specimens had significantly higher δ15N values than contemporary feathers. Given that higher δ15N values are an indicator of feeding at a higher trophic level (Hobson 1990), this suggested a potentially higher utilization of arthropods by prairie chickens in the past.

Sharp-tailed grouse utilize a variety of arthropod prey, however grasshoppers (Orthoptera: Acrididae) are of particular interest as their abundance, diversity, and varying phenology (Lactin et al. 1995) on grasslands provides a reliable food source during the spring and warm season (Johnson et al. 1996, Martin et al. 2000). Sharp-tailed grouse are known to utilize grasshoppers as a significant component of their diet (Jones 1966, Mitchell and Riegert 1994), and arthropod prey are critical for grouse chicks during the first weeks of life (Connelly et al. 1998, Johnsgard 2016). Given the expected impact of climate change on arthropods (Prather et al. 2013) and the influence of agricultural pest management on grasshoppers and other arthropods (Martin et al. 2000), it is prudent to explore trophic relationships between birds and arthropods.

Stable isotope mixing models (SIMMs) such as MixSIAR (Stock et al. 2018) are used to estimate proportional contribution of foods, or food groups, to an organism's diet. Stable isotope mixing models function on the premise that dietary isotope values are reflected in the isotope values of the consumer tissue, after biological processes have been accounted for. However, critical for construction of a useful SIMM is an understanding of the study system and all its inputs. A SIMM for a particular organism should include a baseline of isotope values for all food items consumed by that organism; however, inclusion of food items that are not utilized by the organism and have a substantially different isotope value (such as inappropriate inclusion of C_4 plants), can significantly influence the model results (Torres-Poche 2017). Selection of model parameters, as well as physiological processes undergone by the study organism, should be considered on a spatial and temporal scale appropriate to the study objectives. Stable isotope data can also be used to quantify food web structure in other ways. Trophic position can be estimated relative to the isotope values of primary producers or primary consumers (Post 2002) and ecological inferences can also be made using isotopic niche to explore food web dynamics, intrapopulation trophic variability, and community wide food web characteristics (Layman et al. 2007, 2012).

In our study of sharp-tailed grouse, we estimated feeding relationships between plant food and arthropod prey (insects and spiders) using stable isotope analysis of primary feathers to infer dietary contributions over a 6 month period. Feathers provide a practical source for isotope data that represent the isotope values of nutrient contributions to feather synthesis during the time in which the feather was grown, after the application of an appropriate trophic discrimination factor (TDF). After synthesis, feathers are metabolically inert, making it relatively simple to estimate temporal scale if the molting pattern of the bird is known (Hobson and Clark 1992, Renfrew et al. 2017). Adult sharp-tailed grouse molt their 10 primary feathers between May and October (Pyle 2008) which provides a convenient overlap with the time during which arthropods become available as prey. Given the principles around trophic discrimination of δ^{15}N, and differential values of δ^{13}C depending on source contribution of carbon (Layman et al. 2012), we hypothesised that diet proportions of plant foods and arthropod prey could be estimated from feather δ^{15}N and δ^{13}C over the molting period. Since grouse utilize arthropods opportunistically (Jones 1966), we expected that δ^{15}N values would increase as arthropod prey became available, and that juvenile grouse feathers would reflect high arthropod consumption early in the season and gradually gravitate to an adult grouse diet later in the season.

Study area

Collection sites were located near Spring Coulee, Alberta, Canada (Wild Rose Conservation Site: 49.26°N, 112.98°W) and Warner, Alberta (Twin River Heritage Rangeland Natural Area: 49.24°N, 112.35°W), approximately 46 km apart. Sites were located on native prairie neighboring agricultural land where the foothills fescue and mixed grass natural subregions meet, along the Milk River Ridge (Downing and Pettapiece 2006). Both sites were dominated by native grasses, forbs, and shrubs and were under grazing management by the Alberta Conservation Association (Wild Rose) and local ranchers (Twin River). Sites were known to have one or more leks (breeding grounds) in their vicinity and were both popular hunting areas for sharp-tailed grouse (Meyhoff 2020).

Methods

Sample collection

We obtained sharp-tailed grouse primary feathers from wings donated by hunters in the study area during the 2017 and 2018 fall hunting seasons. We aged and sexed grouse from which wings were donated using wing morphology and molt stage (Caldwell 1980, Pyle 2008), crown and tail feather pattern (Henderson et al. 1967), and ossification of the lower mandible (Linduska 1945). We necropsied a subset of 24 grouse in order to confirm age and sex by examination of testes or ovaries and bursa of Fabricius (Kirkpatrick 1944). We stored wings frozen at −20°C prior to extraction of feathers. We removed primaries 1–10 (P1–P10; Figure 1) from each wing and cleaned following recommendations from Paritte and Kelly (2009).

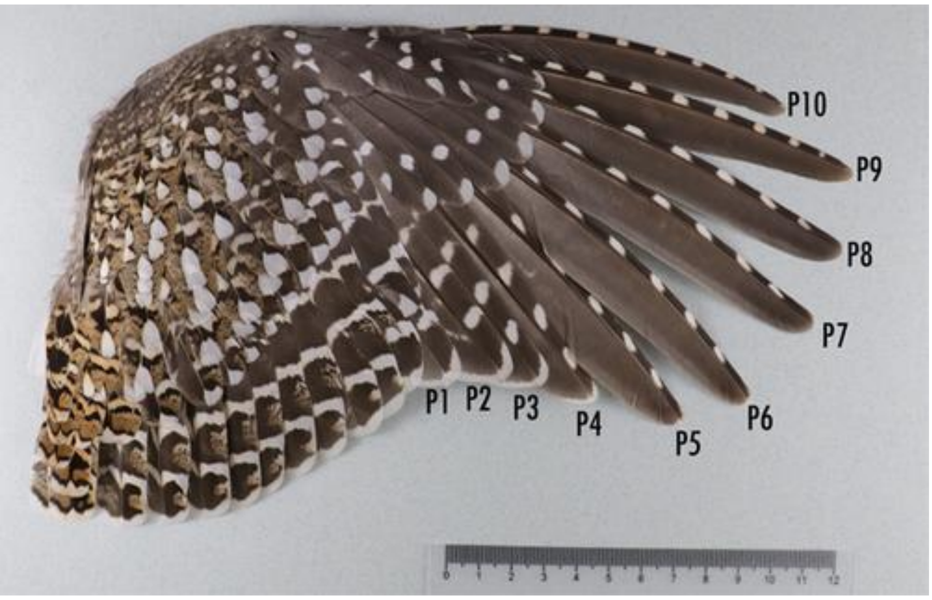

Figure 1. A sharp-tailed grouse wing collected from the Wild Rose Conservation site in southern Alberta, Canada, in 2018 with labelled primary feathers 1–10.

To establish reliable baseline isotope values of potential food items for sharp-tailed grouse, we conducted arthropod and vegetation sampling over a period of 6 months, from May to October 2018. The sample period coincided with the time period when sharp-tailed grouse molt their primary feathers (Pyle 2008) and also covered a time period over which arthropod prey availability changed significantly (Table 1).

Table 1. Relative abundance and relative biomass of arthropod orders estimated from sweep netting (n = 222) at Wild Rose Conservation site and Twin River Heritage Rangeland, Alberta, Canada, in 2018, calculated from dry weight and count data of all captured arthropods.

	May–June		**July–August**		**September–October**	
Order	**Relative abundance**	**Relative biomass**	**Relative abundance**	**Relative biomass**	**Relative abundance**	**Relative biomass**
Araneae	12.3%	14.2%	9.6%	2.9%	9.4%	2.9%
Coleoptera	21.4%	37.4%	3.7%	2.4%	11.2%	4.6%
Diptera	24.4%	6.4%	12.2%	2.3%	30.9%	5.4%
Hemiptera	15.6%	11.0%	62.6%	47.7%	33.4%	16.9%
Hymenoptera	19.1%	9.7%	4.1%	0.8%	3.6%	0.8%
Ixodidae	0.1%	<0.1%				
Lepidoptera	5.7%	11.6%	2.1%	3.8%	1.3%	1.1%
Odonata	0.1%	0.3%	0.2%	0.4%		
Opiliones			<0.1%	0.1%		
Orthoptera	1.1%	9.4%	5.3%	39.5%	10.2%	68.3%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

We sampled plants for isotope analysis intermittently throughout the sampling period as plants emerged, and at different stages of maturity. We sampled wild plants (n = 139) as well as agricultural seeds from nearby cultivated fields (n = 17). We performed vegetation surveys in May as well as in July–

August to obtain a comprehensive list of plant species available to foraging grouse. To the extent possible, we sampled all plants available to grouse as forage from the study area, and we sampled plants that were dominant or were known to be eaten by grouse in replicate 2–4 times. We sampled whole plants (above-ground biomass), stored them in paper bags, and kept them cool, to be transported back to the lab. We obtained prior knowledge of sharp-tailed grouse diet preference by analysing esophageal crops obtained from hunters in the study area (n = 106; Meyhoff et al. 2020) as well as from previous diet studies specific to plains sharp-tailed grouse (Aldous 1943, Kobriger 1965, Renhowe 1968, Sisson 1976, Mitchell and Riegert 1994). When possible, we took plant samples directly to the lab and placed them in a drying oven at 60°C for 48 hr prior to sample preparation. When this was not possible for logistical reasons, we stored plant samples frozen at −20° until they could be placed in a drying oven.

We conducted arthropod sampling via sweep netting from May to October 2018. We visited sites intermittently (30 times over the sampling period, roughly once a week, n = 222 transects) and we performed 5–10, 100-m sweep transects (1 sweep per meter with a 38 cm diameter sweep net) during each visit. We stored sweep collections in perforated plastic bags and placed them in a freezer at −20°C the same day.

Sample preparation

We cleaned each feather by first rinsing it in deionized water with 1% Alconox detergent (Cat. 1104-1). We then shook feathers individually in a 500 ml Erlenmeyer flask containing 300 ml of Alconox solution for 30 seconds and then rinsed each feather 3 times in clean deionized water in the same manner. We replaced the Alconox solution and clean water after every 5 feathers. We dried the feathers at 60°C for 24 hours. Following drying, we sealed each feather in a 50 ml test tube with a screw cap containing 15 ml of 2:1 chloroform:methanol solution and shook it for 30 seconds under a fume hood to remove surface oils. We replaced the solvent after every 5 feathers. We then allowed the feathers to air dry under the fume hood for 24 hours (Paritte and Kelly 2009).

Following cleaning, we prepared feathers (n = 418) for stable isotope analysis following guidelines from Wassenaar and Hobson (2006) and Bontempo et al. (2014). We sampled material from the posterior vane of each feather to obtain the most consistent measurements across feathers. In order to account for potential variability along the length of the feather vane (Bontempo et al. 2014), we cut a narrow strip of feather material, uniform in width and from the center of the posterior vane, from each feather using surgical scissors. Using a modified pipette tip and metal plunger, we placed each feather strip into an 8 × 5 mm tin capsule for stable isotope analysis (Figure 2). To obtain an appropriate target weight for isotope analysis (5 mg), the width of the strip necessarily varied (1–2 mm) according to its length. In order to avoid potential contribution of yolk nutrients to prejuvenal feathers (Romanoff 1944, Blomberg et al. 2013), we excluded 2 mm of the distal portion of the vane when sampling juvenile P9 and P10 feathers (Pyle 2008). We included duplicate feather samples (i.e., sampling the same feather twice and sampling the same primaries from opposing wings of the same bird) to ensure that methods were yielding consistent results.

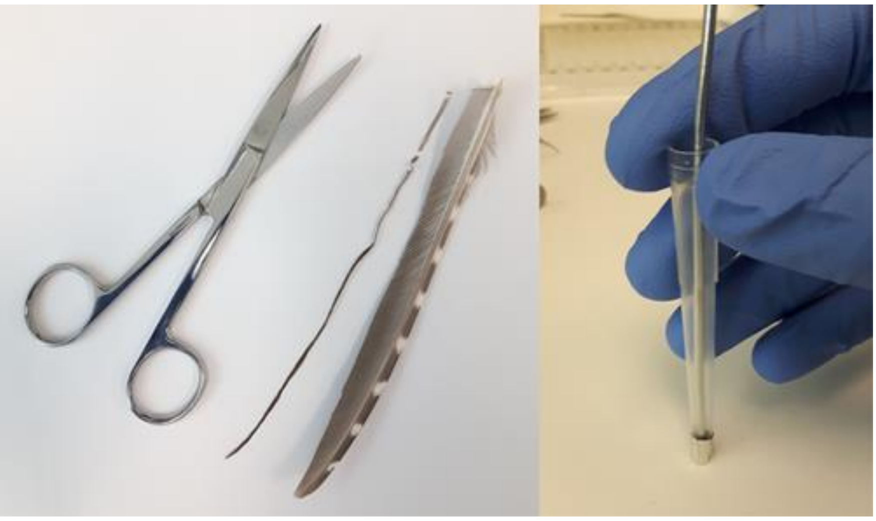

Figure 2. To account for potential isotopic variation along the length of the feathers of sharp-tailed grouse, a strip of feather material was cut from the middle of the posterior vane of each primary feather for stable isotope analysis.

We extracted all arthropods (insects and spiders) from the sample bags in the lab and identified, counted, and weighed them. Identification precision varied between taxa; however, we separated all arthropods to taxonomic order at a minimum. We selected representative arthropods (n = 136) for isotope analysis from each order, depending on knowledge of feeding behavior (i.e., herbivorous or predaceous), phenology, and if the species or taxon was known to be utilized by sharp-tailed grouse. Ten arthropod orders were represented in the isotope analysis including Orthoptera (n = 34); Hemiptera (n = 30); Araneae (n = 29); Coleoptera (n = 20); Hymenoptera (n = 9); Lepidoptera (n = 6); Diptera (n = 4); Opiliones (n = 2); Odonata (n = 1); and Lithobiomorpha (n = 1). Each sample that we prepared for analysis was comprised of several homogenized individuals, and we separated arthropod samples based on 3 collection periods: May–June; July–August; and September–October to track potential changes to arthropod prey isotope values through the study period. We placed arthropods selected for isotope analysis in a drying oven at 60°C for 48 hr after identification and weighing. After desiccation, we homogenized plant and arthropod samples in a Retsch Mixer Mill Type MM 301.

Some arthropods likely contained high amounts of lipid (Rumpold and Schlüter 2013), also reflected in the C:N ratio (Post et al. 2007). To assess the effect of lipids on the arthropod δ13C, we reanalyzed a subset of 28 arthropod samples after lipid extraction. We followed lipid extraction guidelines from Bligh and Dyer (1959) and lab protocols from SINLAB (Stable Isotopes in Nature Laboratory, University of New Brunswick). We used the results from these analyses to derive a linear regression equation to correct all arthropod δ13C values by plotting the change in δ13C after lipid extraction against the untreated C:N ratio.

We analyzed all samples for δ15N, δ13C, percent nitrogen content (%N), and percent carbon content (%C) using a FlashSmart elemental analyzer coupled to a Delta V Plus isotope ratio mass spectrometer (Thermo Scientific Instruments, Bremen, Germany) at the Agriculture and Agri-Food Canada Lethbridge Research and Development Center. We used IsoDat software (Thermo Scientific Co.) to determine elemental concentrations and calculate delta (δ) values. Experimental error determined from isotope standards within the sample sets (n = 235) was 0.40‰ for δ15N, 0.23‰ for δ13C, 0.38% for %N, and 1.67% for %C. The reference materials we used (NIST 8414, NIST 8574/USGS 41, NIST 8573-USGS 40, EDTA, and in house wheat grain and maize stover) spanned a similar range of isotope values as the experimental samples.

Before we could analyze our data using MixSIAR (Stock et al. 2018) in R (version 3.6.2, R Core Team 3.6.1 2019), we examined and manipulated isotope data to ensure that the model input was reliable, accurate, and ecologically coherent. We performed statistical analyses including ANOVA, t-tests, Shapiro Wilk tests, and linear regression in JMP 14 (JMP®, Version 14.3.0. SAS Institute Inc.).

Data analysis

We separated grouse into 4 classes based on age and sex; female after-hatching-year (AHY; adult female; n = 15); female hatching-year (HY; juvenile female; n = 9); male AHY (adult male; n = 8); and male HY (juvenile male; n = 8). We assigned a calendar date to each primary feather according to when it was estimated to have grown. Molting of primary feathers occurs from May–October for adult grouse (Pyle 2008), as such we estimated P1 to have grown May 1, P10 on October 31, and P2–P9 at equal time intervals (21 days) in between. During their first year of life, following their prejuvenal molt (first set of pennaceous feathers), juvenile grouse undertake an incomplete performative molt during the summer. During this molt only P1–P8 are replaced from June–October (Pyle 2008). As such, P9 and P10 in juvenile grouse were treated as having been grown in the spring (May 12), and P1–P8 at equal intervals (20 days) from June 1–October 31.

When testing for differences between grouse classes, we only compared primaries grown during the same time period. Using a 2-way ANOVA, we detected no difference between collection site regarding δ15N and δ13C. We detected significant differences in δ15N and δ13C between age classes (F1,9 = 2.5621, P = 0.0073 and F1,9 = 3.0938, P = 0.0014 respectively for δ15N and δ13C) and in δ15N between sexes in adult grouse (F1,9 = 3.6882, P = 0.0003). Among juvenile grouse, we detected no significant differences between sexes. We combined sex classes for juveniles and kept sex classes separate for adult grouse.

We calculated average isotope values for all C3 plants for use in a 3-source model iteration. The only plants found in the study area that used a C4 photosynthetic pathway were grasses, which were not dominant in the area (Wang et al. 2006, Osborne et al. 2014). Grasses are not reported to be a common diet item for sharp-tailed grouse, and including C4 sources as a separate mixing source when not appropriate would affect the model outcome (Torres-Poche 2017). We further divided C3 plants between berries (snowberry [*Symphoricarpos occidentalis*], rose hips [*Rosa acicularis/woodsii*], chokecherry [*Prunus virginiana*], saskatoon [*Amelanchier alnifolia*]) and agricultural seeds separate from other forbs and grasses for use in a 4-source model iteration. Isotope signals from plant materials did not vary enough across seasons and between sites to warrant separation according to season.

We grouped potential arthropod components of grouse diet in the following manner (hereafter referred to as trophic separation): we calculated a weighted average of δ15N, δ13C, and C and N concentration for predatory arthropods (Hemiptera, Araneae, Coleoptera, Hymenoptera, Diptera, Opiliones, Odonata, and Lithobiomorpha) using relative biomass (RB) data gathered from sweep netting (calculated by total dry weight of arthropods captured via sweep netting over the duration of the study period, separated by order, and averaged over the study period; Table 1). We also determined an average for prey arthropods (Orthoptera weighted by individual species RB and Lepidoptera) based on their RB in the study area averaged over the study period. Between the trophically separated groups there was a significant difference in δ15N (t40 = 7.60, P = <0.001) but not in δ13C or elemental concentrations. The separation roughly reflected trophic separation within the arthropod samples: the first group contained many predatory arthropods and the second group contained mostly herbivorous prey insects. Subdivision into predatory and prey arthropods was only an approximation as both groups contain arthropods that engage in both types of feeding behavior; however, we based separation on average δ15N values which is reflective of trophic level (Post 2002). The standard deviations that we used in the SIMMs for all groups were calculated from the entire respective datasets to appropriately capture the spread of the isotope values for modeling purposes.

We employed 2 source grouping methods in the SIMMs and compared them: a 3-source model using the trophic separation method described above for arthropod sources (1) and (2), and (3) C3 plants; and a 4-source model using the trophic separation method described above for arthropod sources (1) and (2), and (3) C3 leaf material (forbs, grasses, grass-likes, and shrub buds) separated from (4) berries (snowberry, rose hips, chokecherry, saskatoon) and agricultural seeds.

We used MixSIAR (Stock et al. 2018) to estimate diet proportions of plant material and arthropod prey in 3 classes of grouse: adult female (n = 15), adult male (n = 8), and juvenile grouse (n = 17). We ran the mixing model separately for each class, treated each grouse as a random variable, and treated date as a continuous effect. We set Markov Chain Monte Carlo (MCMC) parameters to 300,000 iterations with 3 Markov chains, a burn-in of 200,000 iterations, and a thinning ratio of 1:100. If the model failed to converge with these parameters, we ran it again at 1,000,000 iterations with 3 chains, a burn-in of 500,000, and a thinning ratio of 1:500. We assessed convergence of MCMC chains using Gelman-Rubin and Geweke diagnostic tests (Geweke 1992, Gelman et al. 2014) built into the MixSIAR package.

We used the TDF for feathers derived by Caut et al. (2009) in the analysis of this study (Δδ15N = 3.84 ± 0.26‰ and Δδ13C = 2.16 ± 0.35‰). That is, the C and N allocated to feathers contain slightly more 15N and 13C than the dietary components. We used the experimentally derived TDF from Torres-Posche (2017; Δδ15N = 3.46 ± 0.53‰ and Δδ13C = 1.14 ± 0.28‰) as well as a TDF derived using the Stable Isotope Discrimination Estimation in R (SIDER) package (Δδ15N = 2.82 ± 1.40‰ and Δδ13C = 1.64 ± 1.42‰; Healy et al. 2017) in a sensitivity analysis to test the effect of using different TDFs.

According to the Bayesian approach used in MixSIAR, we used informative priors derived from summarizing previous literature on sharp-tailed grouse summer feeding ecology specific to the plains subspecies (Aldous 1943, Kobriger 1965, Renhowe 1968, Sisson 1976, Mitchell and Riegert 1994) in the mixing model. From this literature we developed a prior using a Dirichlet distribution assuming that grouse consumed 70% plant material, 25% prey arthropods, and 5% predatory arthropods (Table 2). We corrected arthropod δ13C values according to C:N elemental ratios using the experimentally derived formula in this study from lipid extraction and linear regression analysis (Δδ13C = −0.724 + 0.3692 ∗ C:N, R2 = 0.629, SE intercept = 0.281, SE slope = 0.055, P = <0.001, n = 28,) and we corrected plant materials for lipids using the formula derived by Post et al. (2007) for plants with >40% carbon content (Δδ13C = −5.83 + 0.14 ∗ %Carbon, R2 = 0.841, P = <0.001, n = 16). Relatively wide C:N ratios and greater C contents are indicative of greater amounts of lipid C.

Table 2. Summary of sharp-tailed grouse diet proportion analysis, specific to the plains subspecies, from 5 literature sources using esophageal crop and fecal analysis (Aldous 1943, Kobriger 1965, Renhowe 1968, Sisson 1976, Mitchell and Riegert 1994).

	Range	**Mean**	**Median**
Vegetation	0.64–0.79	0.68	0.64
Orthoptera	0.06–0.34	0.25	0.33
Other arthropods	0.02–0.10	0.05	0.03

Unless otherwise specified, SIMMs assume that proportional contribution of C and N from sources are the same. This is only a reasonable assumption in the case where food sources have similar C and N concentrations (Phillips and Koch 2002). MixSIAR allows for the incorporation of elemental concentrations of sources which are used to weight the proportional contributions of sources in the model estimate in scenarios where elemental concentrations are significantly different among sources (Stock et al. 2018). Given the differences in elemental concentration between plant and arthropod sources in this study, we used concentration dependence during modeling. We ran a series of repeat model iterations to assess model sensitivity to changes in important parameters. We used the 3-source model structure using the adult female grouse feather dataset in a sensitivity analysis that assessed the influence of changes to TDF, lipid correction, and informative/non-informative priors.

We used The SIBER package (Stable Isotope Bayesian Ellipses in R; Jackson et al. 2011) to calculate isotopic niche dimensions (Layman et al. 2007) to compare relative resource use in iso-space between grouse sex and age classes. We compared Bayesian ellipses by calculating the probability that the posterior distributions of ellipse sizes were different. For evaluation, we determined the proportion of posterior draws that were different from another ellipse as a proxy for the probability of a difference (Jackson et al. 2011).

We calculated percent protein content from nitrogen concentrations using a nitrogen to protein conversion factor (kp) for arthropods (kp = 4.76; Janssen et al. 2017) and plants (kp = 4.43 for dicots; kp = 4.37 for monocots; Yeoh and Wee 1994). The conventional kp value of 6.25 overestimates protein content of whole body arthropods due to the presence of nonprotein nitrogen in chitinous materials, nucleic acids, phospholipids, and ammonia in excreta (Janssen et al. 2017).

Results

The isotope biplot showed a clear trend of diet change for the different classes of grouse (Figures 3 and 4). Model outcomes differed according to the grouping of food sources. In the 3-source model the proportion of arthropod utilization was estimated to be much higher (0.70 on average) than expected (Table 2) through the entire study period. The 4-source model introduced larger credible intervals (CI) in October (up to 0.99 CI for MAHY) with the inclusion of berries and agricultural seeds as an additional source. The 4-source model also estimated high utilization of arthropods and estimated a high utilization of berries and agricultural seeds in the fall (Table 3).

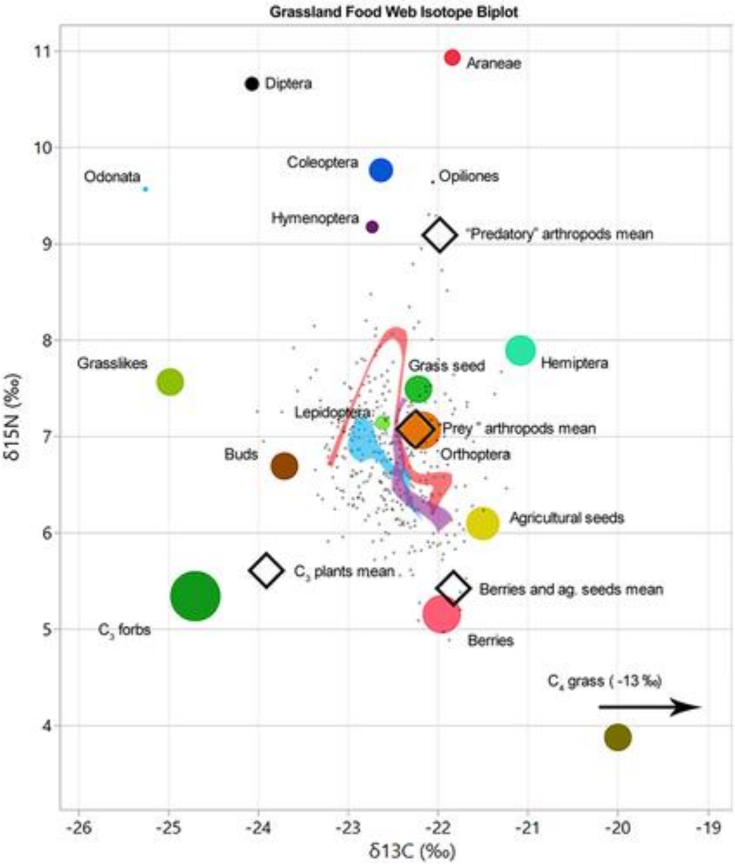

Figure 3. Isotope biplot of a grassland ecosystem food web in southern Alberta, Canada. Colored points are average source values, and size corresponds to relative available biomass. Black diamonds represent averages used in the SIMM. The thickened lines track the isotope measurements of sequentially grown primary feathers in adult female (purple), adult male (red), and juvenile (blue) sharp-tailed grouse. Semi-transparent black points are individual feather isotope values. Source isotope values are corrected for trophic discrimination using TDF from Caut et al. (2009).

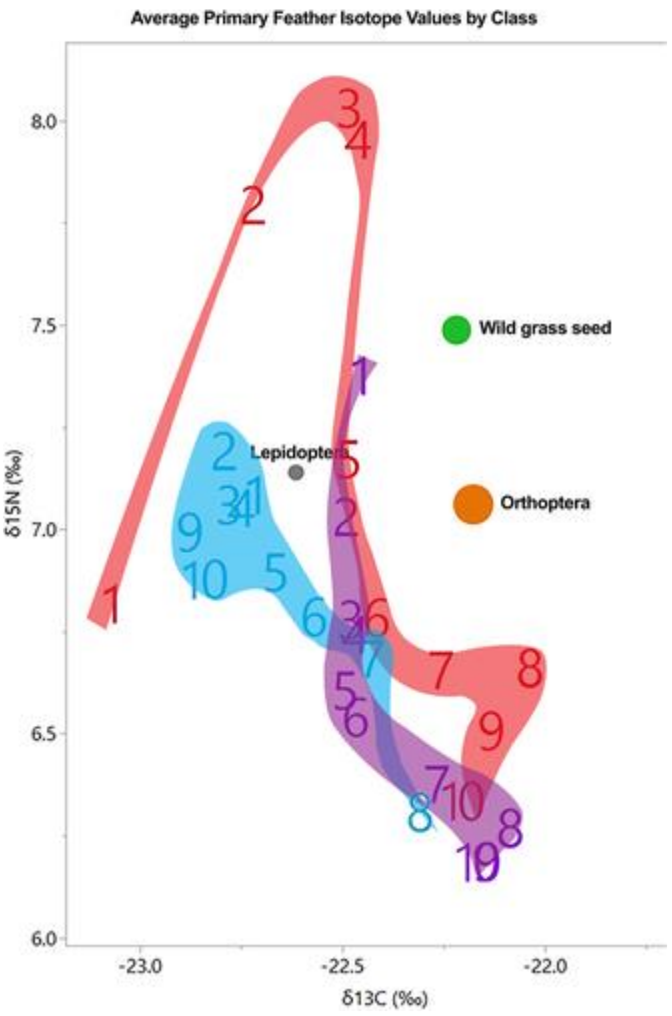

Figure 4. Isotope biplot showing seasonal changes to sharp-tailed grouse primary feather isotope signals in southern Alberta, Canada. Colors correspond to adult female (purple), adult male (red), and juvenile (blue) sharp-tailed grouse. The numbers represent the biplot position of the average isotope value of the corresponding primary feather. Note that P9 and P10 in juvenile grouse are grown during the prejuvenal molt, before P1–P8 (preformative molt), see text for full explanation (Pyle 2008). Source isotope values are corrected for trophic discrimination using TDF from Caut et al. (2009).

Table 3. Stable isotope mixing model comparison of overall average diet proportion estimates for sharp-tailed grouse in southern Alberta, Canada, in 2017 and 2018 using feather stable isotopes in MixSIAR with standard deviation in parentheses.

Grouse class	**Source**	**3-source model diet proportions**	**4-source model diet proportions**
Adult female	Predatory arthropods	0.08 (0.03)	0.04 (0.02)
	Prey arthropods	0.68 (0.07)	0.32 (0.13)
	Berries and ag. seeds	-	0.44 (0.16)
	C_3 Plants	0.23 (0.07)	0.19 (0.07)
Adult male	Predatory arthropods	0.18 (0.10)	0.16 (0.09)
	Prey arthropods	0.55 (0.14)	0.19 (0.15)
	Berries and ag. seeds	-	0.46 (0.15)
	C_3 Plants	0.24 (0.13)	0.15 (0.08)
Juvenile	Predatory arthropods	0.17 (0.05)	0.16 (0.05)
	Prey arthropods	0.45 (0.08)	0.50 (0.09)
	Berries and ag. seeds	-	0.10 (0.05)
	C3 Plants	0.38 (0.07)	0.23 (0.06)

The 3-source model estimated the highest proportion of arthropod utilization for adult grouse. Adult female grouse were estimated to utilize the highest proportion of prey arthropods (0.33 in May, 0.68 in August, and 0.89 in October; Figure 5A, C), and all classes were estimated to utilize other predatory arthropods less. The adult male grouse model had the most uncertainty, reflected in the credible intervals, as well as the most variability in diet proportions over the study period (0.11 in May, 0.54 in August, and 0.92 in October for prey arthropods; Figure 6A, C). The juvenile grouse model showed a similar diet composition and temporal change to adult female grouse, but with a higher estimate of forb utilization in the early season (Figure 7A, C).

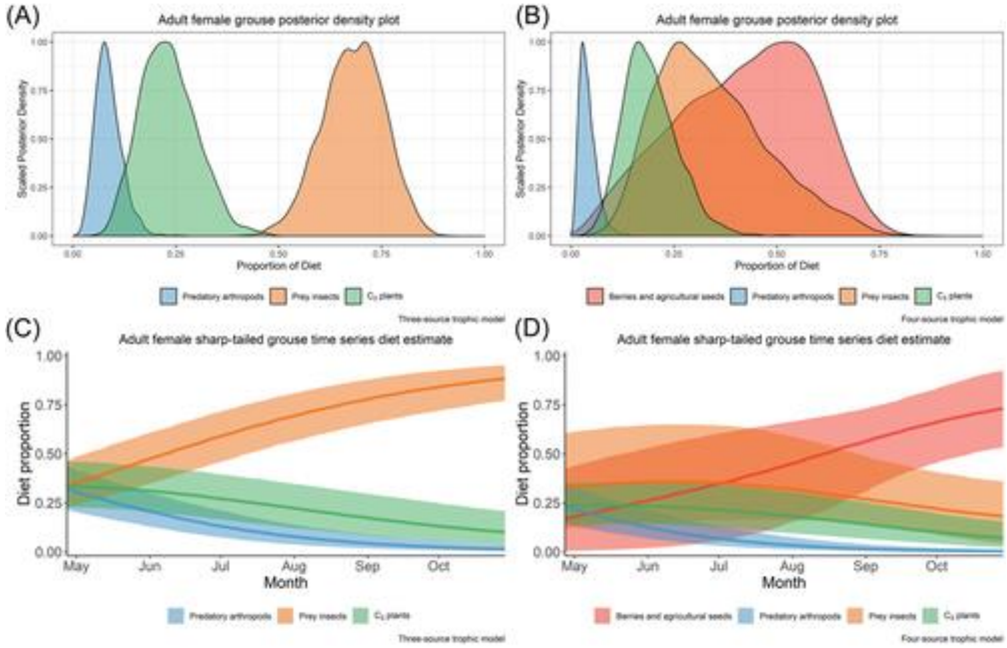

Figure 5. Comparison of posterior density plot and diet across time estimate for adult female sharp-tailed grouse in southern Alberta (A and B). The posterior density plot is a probability distribution for the proportions of each diet source. Diet across time estimates (C and D) are given via the median estimated value (line) and the 95% credible interval (ribbon).

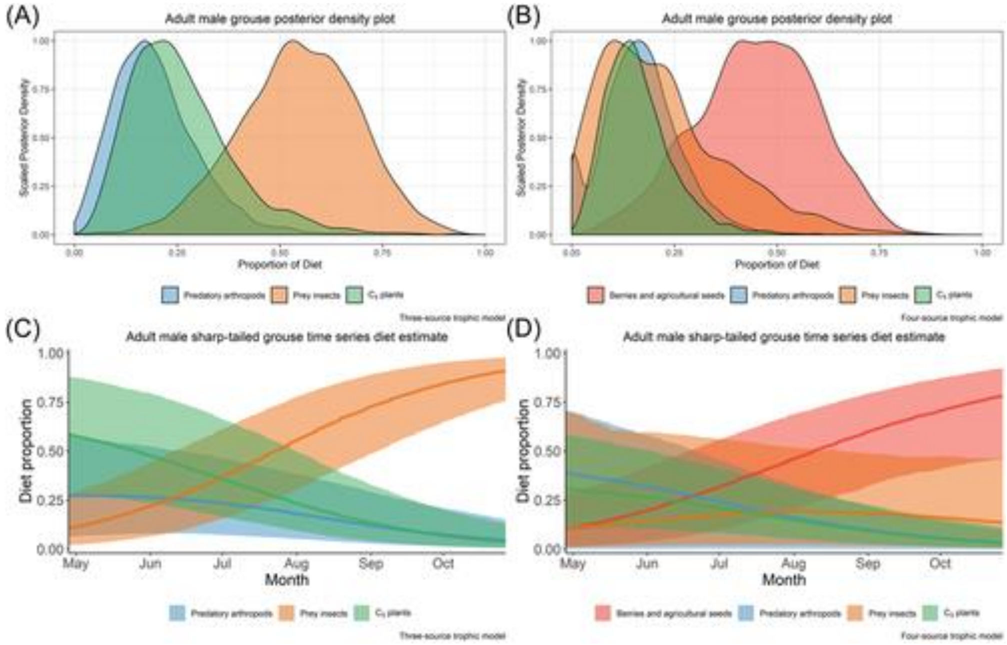

Figure 6. Comparison of posterior density plot and diet across time estimate for adult male sharp-tailed grouse in southern Alberta (A and B). The posterior density plot is a probability distribution for the proportions of each diet source. Diet across time (C and D) are given via the median estimated value (line) and the 95% credible interval (ribbon).

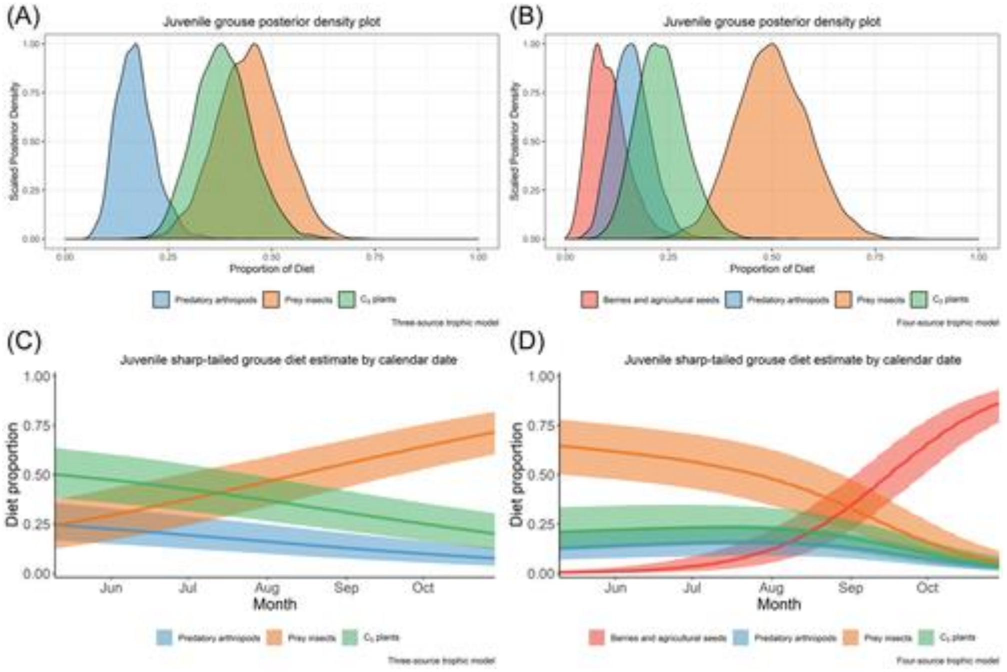

Figure 7. Comparison of posterior density plot and diet across time estimate for juvenile sharp-tailed grouse in southern Alberta (A and B). The posterior density plot is a probability distribution for the proportions of each diet source. Diet across time estimates (C and D) are given via the median estimated value (line) and the 95% credible interval (ribbon).

The 4-source model showed high levels of uncertainty in estimates for adult grouse (up to 0.74 CI for FAHY and 0.99 for MAHY), but not for the juvenile grouse model (the largest CI was 0.31). All models estimated high arthropod utilization in the early season (0.57 for female, 0.51 for male, and 0.79 for juvenile), and a high proportional utilization of berries and agricultural seeds in the late summer and fall for all classes (between 0.75 and 0.87). The adult male grouse model was the had the largest CIs (Figures 5D, 6D, and 7D).

Our sensitivity analysis indicated that changing the parameters (informative versus uninformative priors, lipid correction, and TDF) of the 3-source model had no significant effect on diet proportion estimates; however, changes generally resulted in higher estimates of arthropod utilization. Bayesian ellipses showed that relative resource use in isotopic niche space was similar for adult female grouse and juvenile grouse (probability of a difference in ellipse size = 25%), and larger for adult male grouse (probability of a difference in ellipse size between adult female and adult male grouse = 99%). Seasonal niche estimates showed changes to ellipse areas over the study period. Changes were mostly non-significant (within 95% credible intervals), except for juvenile grouse that showed a significantly larger ellipse area during the September–October period (posterior probability of a difference = 100%). We present the average protein content of plant and arthropod samples estimated from nitrogen-to-protein conversion factors in Table 4. Average protein content was significantly different between plant and arthropod food items (t16 = 22.18, P = <0.001).

Food type	Protein (%)
Plants	
Agricultural seed	16.8
Berry	6.7
Forb	12.3
Sprouting grass (C_3)	15.0
Grass (C_4)	7.0
Grass seed (C_3)	9.2
Grasslike	11.6
Shrub bud	9.5
Plant average	11.02
Arthropods	
Araneae (Spiders)	58.3
Lithobiomorpha (Centipedes)	53.4
Coleoptera (Beetles)	47.2
Diptera (Flies)	56.2
Hemiptera (True bugs)	49.6
Hymenoptera (Ants and wasps)	53.4
Lepidoptera (Moths and butterflies)	47.9
Odonata (Damselflies)	58.8
Opiliones (Harvestmen)	58.4
Orthoptera (Grasshoppers and crickets)	56.4
Arthropod average	54.0

Table 4. Summary of estimated protein content of potential food items of sharp-tailed grouse (arthropods n = 139, plants n = 146) in southern Alberta, Canada, in 2017 and 2018 calculated from nitrogen concentrations using conversion factor (kp) 4.76 for arthropods, 4.43 for dicots, and 4.37 for monocots.

Discussion

A limitation of the SIMMs presented in this study was that they did not account for seasonal change in available plant food, i.e., the availability of ripened berries in the fall. However, the 3-source model provided an appropriate diet estimate during early- and mid-season, while the 4-source model was better suited for estimating diet proportions of grouse later in the season. From the sequential plotting of primary feathers on an isotope biplot (Figure 4), it was apparent that a diet shift occurred for all classes of grouse, and that they gravitated toward the same food source in the late season: ripened berries and agricultural seeds. Of interest as well, from the diet estimate relative to calendar date, was the trend across all grouse classes of early season use of predatory arthropods. The progression of resource use from predatory and prey arthropods in the early season to more prey arthropods in the middle and late season is consistent with arthropod prey availability for grouse. Ground dwelling arthropods like spiders (Araneae) and beetles (Coleoptera) may constitute an important early season food source for grouse (Table 1).

The 3-source model sources were isotopically different enough to allow for a confident estimate of diet shift over time, except in the case of adult male grouse, and likely represented an appropriate mixing system for grouse during early- to mid-summer. The high utilization of arthropods that was estimated was expected during this time (Aldous 1943, Kobriger 1965, Renhowe 1968, Sisson 1976, Mitchell and Riegert 1994). However, the degree to which arthropods were estimated to be utilized was much higher than expected from conventional diets for all grouse classes. The estimate from the 3-source model was unlikely to be representative of the actual proportion of biomass intake of the modeled food sources for all classes; however, it may be accurate in the context of isotopic routing which has the potential to confound mixing model results.

An inherent assumption in SIMMs is that elements from consumed foods (after the adjustment from the TDF) are evenly distributed throughout the consumers' tissues. This is not a realistic assumption (Martinez Del Rio et al. 2009), and it is up to the researcher to be mindful of the type of consumer tissue that is being sampled and the metabolic process that is involved in its synthesis. In cases where isotopic routing occurs, the isotope value of a consumer tissue does not reflect that of the bulk diet but rather the portion of dietary nutrients that went into producing that tissue. Isotopic routing has been found most prevalent in omnivores and may vary with diet quality (Gannes et al. 1997, Layman et al. 2012). Podlesak and McWilliams (2006) reported that the routing of δ15N and δ13C differed depending on diet composition, and that when yellow-rumped warblers (*Dendroica coronata*) were fed a high protein diet (such as one that included arthropods) the δ15N values of their proteinaceous tissues reflected those of dietary protein very closely. Podlesak and McWilliams (2006) concluded that wild birds consuming arthropods opportunistically may have tissue δ15N values that disproportionately reflect the protein obtained from arthropods. Therefore, it is possible that protein assimilated by sharp-tailed grouse from ingested arthropods were preferentially allocated to the synthesis of their feathers. Cystine and methionine are amino acids important to the production of feathers in gallinaceous birds (Bearhop et al. 2002, Blair 2008) and are found in much higher concentrations in the proteins of arthropods than in plant foods (Savory 1989). Lipids, carbohydrates, and energy stores are thought to have a minimal contribution to the production of feathers, further suggesting that isotope signals of feathers should be expected to reflect dietary protein rather than bulk diet (Murphy 1996, Bearhop et al. 2002). Thus, the isotope signals found in grouse feathers may be more reflective of the proteinaceous component of their diet, i.e., arthropods, than other diet constituents.

Early season diet proportion estimates were similar for juvenile grouse and adult female grouse. Given that grouse chicks are known to consume arthropods almost exclusively during the first few weeks of life (Blomberg et al. 2013, Johnsgard 2016) we expected this to be reflected in the isotope signal of the first primary feathers (P9 and P10) in juvenile grouse. While estimated arthropod utilization was high in the 3-source model in the early season for juvenile grouse (49%), it was not higher than that of adult females (66%). The estimate was significantly higher for juveniles in the 4-source model (79%), however the inappropriate inclusion of berries in the early season likely distorted the estimate. The discrepancy between known foraging habits and model estimates for juvenile grouse may also be explained by isotopic routing: grouse chicks require adequate nutrients for rapid production of flight muscles, feathers, and internal organs simultaneously. Rapid growth may affect isotopic routing to feathers in 2 ways. First, nutrients obtained from arthropods may not be preferentially routed to the production of feathers, as in adult grouse, but towards the production of other proteinaceous tissues like muscle, as well as internal organs and feathers. The first pennaceous feathers produced by grouse chicks during that time are indeed of poor quality, and most of them (P1–P8) are replaced that same summer (Pyle 2008). Second, digestion in juvenile grouse does not occur in the same way as in an adult grouse due to the time it takes for their cecae to develop. Once developed, the cecae allow grouse to extract more nutrients from poor quality foods (Leopold 1953, Remington 1989). The absence of fully developed cecae in juvenile grouse could lead to differential isotope fractionation and allocation as compared to adult grouse (e.g., methanogenic archaea or bacteria could fractionate anabolized 13C resulting in tissues more enriched in 13C). The need for juvenile grouse to allocate nutrients to full body growth, coupled with differential digestive efficiency may explain why the isotope values obtained from the first primary feathers (P9 and P10) did not reflect diet in the same manner as in adult grouse. This hypothesis is further supported by evidence from other studies, including one using Japanese quail (*Coturnix japonica*; Hobson et al. 1993), that indicated lower δ15N values in organisms that were growing (Martinez Del Rio et al. 2009).

The 3-source model provided insights into the feeding ecology of sharp-tailed grouse during the spring and early summer. However, given what is known about late summer and fall grouse feeding ecology (i.e. high utilization of berries), the 3-source model is unlikely to have provided an accurate estimate of late season diet. Esophageal crop analysis from grouse harvested in the study area during October estimated that berries (snowberry, rose hips, chokecherry, and saskatoon) made up 55% of grouse diets by dry weight, and occurred in 88% of crops (Meyhoff et al. 2020). It is therefore not surprising that the 4-source model that included berries and agricultural seeds as a separate source estimated high utilization of that source during the late season (between 75–87%), albeit with high uncertainty for adult grouse. Due to their isotopic similarity, agricultural seeds were necessarily combined with berries for modeling purposes. However, although agricultural seeds are known to be consumed by grouse in October (35% by dry weight), the frequency of occurrence of agricultural seeds (18%) was much lower than berries (88%), and only found in the crop of 1 juvenile grouse out of 69 (Meyhoff et al. 2020). Therefore, diet proportions estimated for this source were assumed to consist mostly of berries.

The early and mid-season estimates using the 4-source model were not significantly different from the 3-source model for adult grouse (95% CIs overlapped); however, uncertainty of the 4-source model estimates given the range of credible limits was high, except in the juvenile grouse model. The 4-source model also estimated higher than expected combined arthropod utilization during October (9–19%), relative to what was observed from esophageal crop analysis (3.4% by dry weight; Meyhoff et al. 2020). The discrepancy between the model estimate and esophageal crop analysis further agrees with the isotopic routing hypothesis that nutrients gained from high protein food sources may be preferentially allocated towards feather synthesis.

The ellipses produced using the SIBER package (Jackson et al. 2011) reflected the range of isotope values measured in grouse feathers. Small ellipse areas suggested a narrow feeding niche, and a large ellipse suggested more variation in food selection. We note that the isotopic niche, although related to trophic niche, is not directly representative (Jackson et al. 2011, Layman et al. 2012). The reason the isotopic niche is not representative of trophic niche is likely due to many of the same issues previously discussed surrounding the interpretation of isotope values relative to the tissue being sampled, the spatial and temporal scale, and metabolic factors. Adult male grouse appeared to have the most diverse diet between classes, however, changes observed throughout the season were not significant. This observation was consistent with known behavior in the context of grouse hens and chicks foraging in closer proximity to each other while male grouse would not be expected to have the same spatial constraints on their foraging habits (Roersma 2001). As might be expected from juvenile grouse, either as a product of actual diet change or of differential isotopic routing, or both, a significant change in ellipse size was observed between May–August and September–October (probability of a difference = 1.0). This observed change in juvenile grouse diet was also consistent with brood rearing behavior. Grouse broods break up in September (Bergerud and Gratson 1988, Roersma 2001), which coincides approximately with the measured change in isotopic niche (i.e. the larger ellipse), which can be attributed to a greater diversity in food selection among juvenile grouse, and a diet more similar to that of an adult grouse, after leaving their brood and foraging on a broader spatial scale. It is important to remember, however, that ellipse size only reflects variation in diet, and does not reflect the apparent shift in diet by juvenile grouse that is evident from the SIMM results.

Conclusion

The 3-source model likely represented the model structure that most accurately reflected the mixing space from which sharp-tailed grouse were feeding in the early and mid-season, while the 4-source model was more representative of late season food availability. However, due to the similarity in δ13C of berries and prey arthropods, model estimation precision was poor for the 4-source model. Given the occurrence of berries as a food source only later in the season, it was possible to obtain reliable estimates of early- to mid-season feeding relationships using the 3-source model that excluded berries as a potential food source. High estimates of arthropod utilization were reasonable in the context of isotopic routing, which was hypothesized to be causing nutrients from protein rich arthropod foods to be preferentially allocated to the synthesis of primary feathers. Isotopic niche (i.e. ellipse area in isospace) was also found to reflect known feeding behavior and differences among male, female, and juvenile grouse.

Our results indicate that stable isotope measurements of sharp-tailed grouse primary feathers can elucidate information about feeding ecology, relative resource use, and nutrient allocation, albeit with significant limitations. We found that arthropod prey was more important to feather growth than would be suggested by conventional observational dietary studies, most likely due to their high protein content. Grasshoppers represented the most abundant arthropod prey by relative biomass, and prey arthropods (grasshoppers being the main constituent) were estimated to contribute a large amount of nutrients towards feather growth in this study. The prevalence of grasshoppers in the summer diets of grouse is also reflected in conventional diet study literature. As such, grasshoppers are likely the main source of nutrients used for feather synthesis in sharp-tailed grouse.

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Clever heads win fair ladies. Lekking observations of a male capercaillie through seven consecutive years

Arne Flor

For the last 35 years I have followed and documented the activity on several capercaillie lekking grounds in Agder County in Southern Norway. Activities have been documented by filming the displaying birds with digital video cameras. Since 2009 I have recorded display activity on one specific capercaillie lek in Froland municipality, also Agder County. The capercaillie lek faces north in a hill at about 250 m above sea level. The forest consists of old pine trees (*Pinus sylvestris*) with some old spruce and birch trees interspersed. The ground vegetation mainly consists of blueberry (*Vaccinium myrtillus*), and heather (*Calluna vulgaris*) around the small elevations where males are displaying. The capercaillies display on patches with bare rock, almost void of vegetation (Figure 1).

Figure 1. Center spot of the capercaillie lekking area, with camouflage hide on elevated platform. Display activities and mounting almost exclusively take place on such patches with bare rock and (at most) patches of short grown moss.

The lek has been followed from a camouflage hide erected some 1,5 m above ground close to the center, a camouflage hide on the ground close to the eastern display ground (Figure 1), and with eight wildlife cameras spaced out to cover several display centers. The hide has always been set up several weeks before the peak lekking period to avoid disturbing the bird´s display activities. The peak of the capercaillies´ display activity was revealed by wildlife cameras transmitting images to my cell phone. I was thus able to attend the lekking ground before and during the peak mating period, often referred to as the “hen week”. From 2016 to 2022 I have been able to follow one specific male and his success as a real “Don Juan”, attracting females and avoiding fatal fights with other prime males. Based on his unusual behavior I have named him “the clever one”. This is a description on some of his behavior which I have been able to record.

To identify individual birds, banding is the most common method for following individuals over many years. I have however never captured or banded birds at any of the capercaillie leks I have monitored and observed. Birds which show individual variation in plumage characters may however be identified without such banding (Solheim 2016). Although a moulted feather may not be replaced by a feather with exactly similar patterns, the patterns may still be stable enough to allow identification of individual birds (Hoy et al. 2016, Selås et al. 2017, Solheim et al. 2018). Male capercaillie show considerable individual variation in the amount of white markings on their tail feathers, and also with respect to the undertail coverts and vent feathers (Figure 2). While some males may have almost black tail feathers and coverts, others have large areas with complicated white spots and patterns. The amount of white or absence of such markings seems to follow the capercaillie individuals across moult sequences. The male I have named “the clever one” had substantial amount of white in his tailfeathers. The under-tail coverts however seemed to be much more consistent regarding pattern and appearance judged by my images of the back side of his erected tail fan (Figure 3). Based on these images and the difference to other males recorded at the lekking area, I concluded that these images must be of the same male from 2016 to 2022.

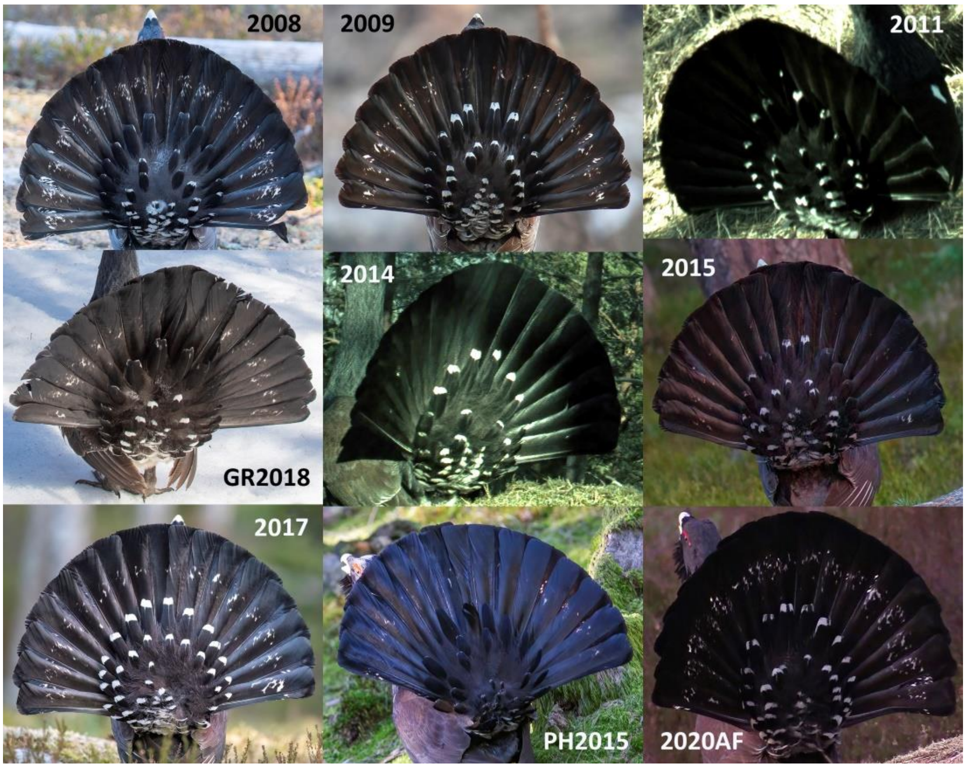

Figure 2. Eight different capercaillie males from other display grounds, and «the clever one» (2020AF), showing differences both in tail feather colouration but also differences in the amount of white in undertail coverts and vent feathers. Photos: Roar Solheim and Arne Flor (2020AF).

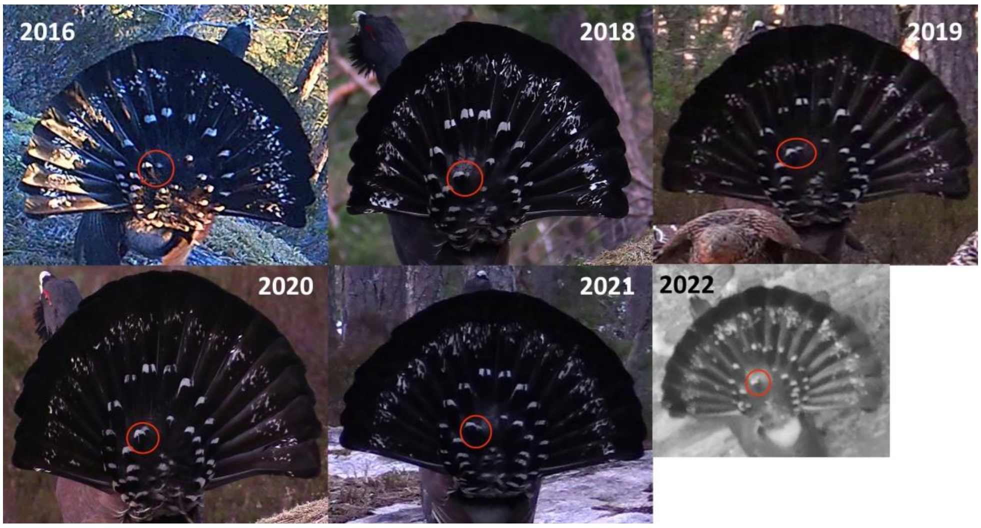

Figure 3. Back side of tail fan of «the clever one» in 2016 and 2018-2022. A repetitive anomaly with one unusually short vent feather is marked with red circle. Note also similarities in white and dark central streak along rachis of the six longest undertail coverts. In 2022 an image of this male was captured on a wildlife camera in night mode only, thus presenting a black and white image in lower resolution than the other images.

On March 14, 2016,”the clever one” appeared on a wildlife camera that I had mounted at the center of a capercaillie display ground (see Figure 4). This male had many white spots on the tail feathers and displayed with his tail fan fully erected. Judged by the images captured on the camera, this male showed aggressive display towards another male bird, as his neck feathers were fully bristled.

On April 13, the clever male was back at the center of the lek. He displayed actively with two females on the ground. The following day he displayed in the same place, but without any accompanying females. On April 15, the camera captured the clever male and at least five females seen in the image frame together with him.

On April 19, the clever male was absent and there was a new capercaillie male together with the females. This new capercaillie male was obviously the new lead male or "chief" at the center of the lekking ground. The clever one was not to be seen. The new capercaillie male had at most 10 females around him simultaneously on the lek center.

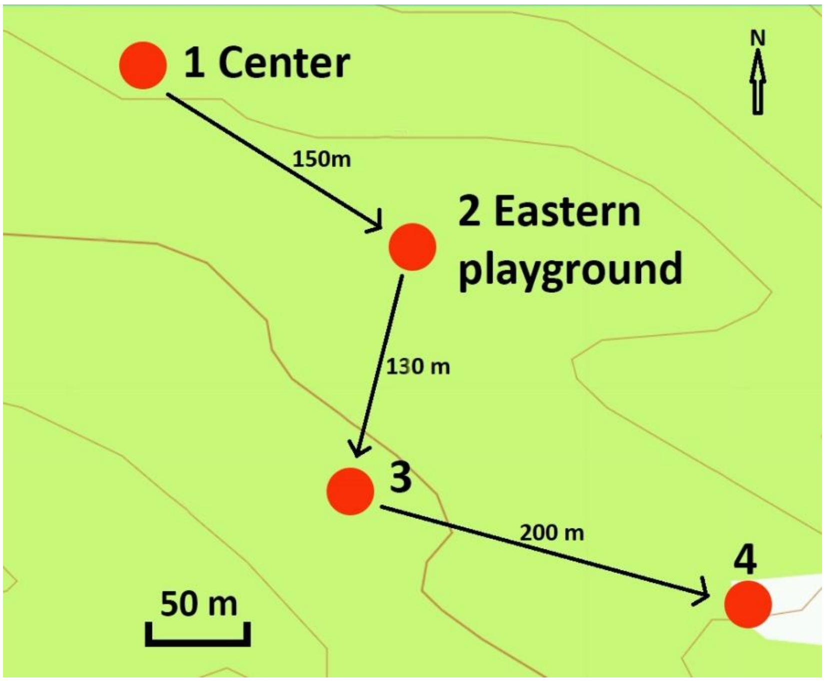

Figure 4. Map of the display ground showing distance and direction to spots where the clever one moved to avoid conflicts, followed by the females. Numbersare referred in the text.

On April 28, 2016, the clever male appeared on a spot some 150 meters east of the lekking center (Figure 4; spot 2). He had obviously established his display patch at this new site, as he displayed with fully erected tail fan and showed aggressive neck bristling. On May 15, at the time for remating of females having lost their clutches, the clever male displayed similarly on this same spot.

On April 14, 2017 the male at the center of the lek was the same individual as the previous year, judged by his overall tail plumage characteristics. At his display center I recorded at most 12 females gathered simultaneously. On May 1, a new male had taken over this center spot at the lekking ground, and the previous male was never observed again. Neither was I able to observe or record the clever male, but a lot of male droppings at his display ground used in 2016 indicated that he had been displaying there also in 2017.

In 2018 much of the display activity had moved to a large patch of snow situated midway between the 2017 lekking center and the eastern display ground of the clever male. I observed that he was trying to attract the females towards his own display center. I thus moved my camouflage hide over to the snow patch and found that the activity there took place for a short period only, at the end of the lekking period. Most of the lekking activity seemed to have moved to the eastern display ground, where the clever one displayed, about 150 meters from the former center. From a new hide spot, I was able to follow the lekking activities until the end of April. It seemed that the clever male functioned as the lekking chief and that he undertook most of the copulations.

In 2019, the clever one was back at the eastern lekking ground. He was the undisputed chief, and he was chosen by the almost all the females. Some challengers appeared, but they were all chased away by the clever male. In 2020, the clever male was back on the lek again. At most I recorded that he was attended by as many as 20 females simultaneously. At the peak of the mating week I recorded as many as 29 copulations in one morning. In total I recorded and filmed 46 copulations which the clever male undertook during the 2020 season.

In 2021, the clever male was once again back on the lek. The females perched for several days in the trees above the center of the eastern display ground, not venturing to the ground. Several females flew around and checked out other capercaillie males, which were displaying on small areas near the eastern display ground. Several times a certain capercaillie male came up on the display ground of the clever male and challenged him. These encounters often ended in beak pecking and aggression, but also in fights. One fight started next to the center before the two males moved up onto the territorial display ground itself. The fight lasted several minutes, and it all looked very brutal. The challenger landed some heavy punches and the clever male ended up backing off and walking away. The challenger displayed like a proud rooster over the playground and down the hill, confident that he would have all the females on his display spot the next morning. But the following day there was no sign of females attending the challenger. Not even the on the day after was I able to see any females on his spot. However, two days later still, I was able to observe that display activities took place some 130 m from my hide (Figure 4; spot 3). There were several male capercaillies running after females, and one of these was the clever one.

Two days later, I could observe through my binoculars display activities some 130 meters from my tent (spot 3). There were several capercaillie males running after the females, and one of them was the clever one. It seemed that he had been able to attract the females to his new display spot. I thus mounted a wildlife camera to cover this display area. The film from the camera showed that the females chose the clever one as mating partner, and he seemed to be in full control of the activities. I observed that he victoriously engaged in some fights with other males. Even the male which had challenged him and driven him off a few days earlier turned up to challenge him again. The clever one once again backed off and pulled away, and also this time he was followed by the females. I did not see this male again this spring.

In 2022, I was excited to see what the situation would turn out to be on the eastern side of the lekking ground. A new male was playing in front of my hide. Once again, I could observe through my binoculars that there were several capercaillies on the area 130 meters away from the eastern display ground. A wildlife camera was mounted at this spot to disclose which male was displaying there this season. To my surprise the clever male once again held this display spot and had assembled 16 females! Some fights were recorded between him and some other males, and at the very end he again pulled away, moving some 200 meters further east (Figure 4; spot 4). Once again, he was followed by the females.

My observations of this clever male indicate that it may not necessarily be the male that win the fights who end up attracting the females. This male avoided serious conflicts and still ended up attracting most of the females. He must obviously have possessed some qualities which the females preferred over the more “brute” males. What these qualities may be is however not obvious to me.

Male capercaillie are only able to establish their own display territory at the age of 3 years (Hjorth 1996). The clever male must thus have been at least 3 years old when I observed him for the first time in 2016, with an established display territory. This male must thus have been at least 9 years old in 2022. I have never before been able to follow a specific male capercaillie for so many years on a lekking ground, and record females following the same male for at least five consecutive mating seasons.

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Last run for the Hazel Grouse in the Vosges Mountains, France.

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Introduction

In Western Europe, the Hazel Grouse has faced a long-term decline throughout the twentieth century. While this species formerly occurred in lowlands areas, its distribution is now mostly restricted to mountain areas. This was specifically the case for *Tetrastes bonasia rhenana* - Kleinschmidt 1941, a subspecies with a limited historical distribution range encompassing east Belgium, south-east Germany, Luxemburg and north-east France. Recent field investigations revealed that *T. b. rhenana* can be considered extinct everywhere except a small remnant population in the Vosges Mountains, probably broadly genetically introgressed by the neighbouring populations of *T. b. styriaca* still present in the Jura and the Alps (see synthesis in Schreiber & Montadert, 2018).

Due to its secretive behaviour, the Hazel Grouse is the less monitored grouse species in Europe and the Vosges population doesn't make an exception to the rule. The only available data allowing a rough estimate of regional trends are the surveys undertaken in France every decade since 1960 (Deloche & Magnani 2002, Buffet & Dumont-Dayot 2011, Dos Santos et al. 2021). These surveys give the presence-absence status in every region for the six galliform species living in France. The tremendous shrinking of the distribution range of Hazel grouse in north-east France is clearly demonstrated by these surveys, with the Vosges constituting the last refuge for this population (Dronneau 2018).

With the aim to better document the present status of Hazel Grouse in the Vosges, field work was undertaken during the winters 2019-2020 and 2020-2021. 69 sites where selected in different parts of the Vosges Massif (Figure 1). All of them were known to be occupied recently, during the period 2010-2014 for the oldest and for 27 out of 69, still occupied during the 2015-2019 period.

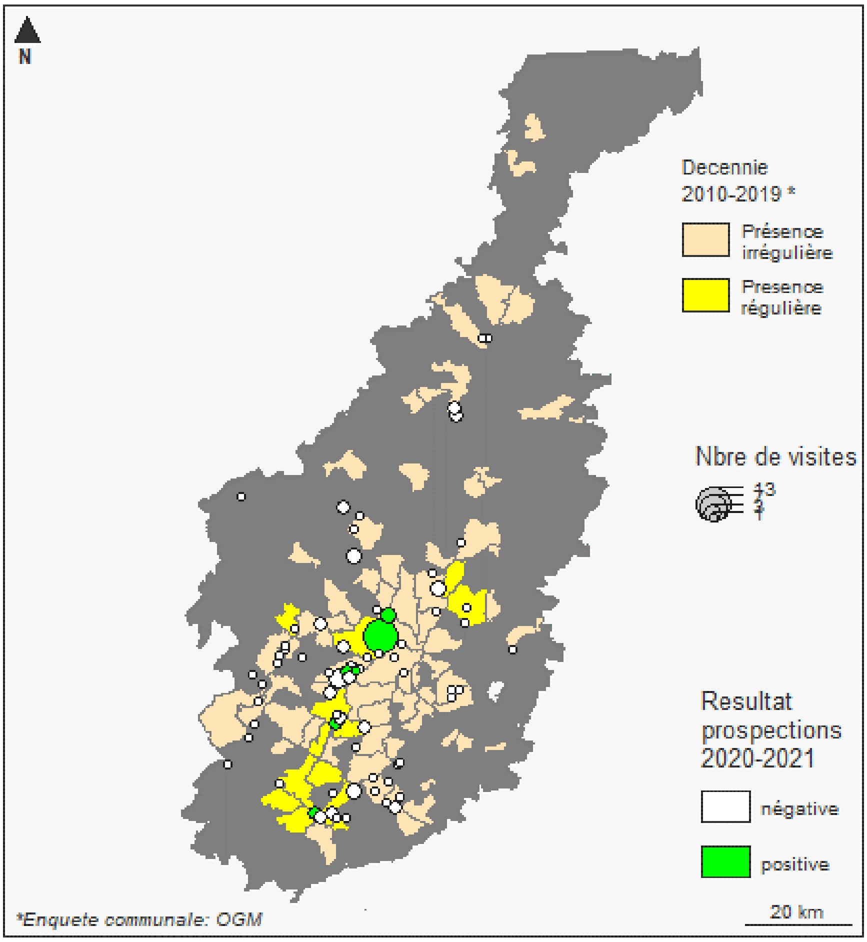

Figure 1. The Vosges Massif with the location of the 69 prospected sites for estimating Hazel Grouse occurrence during two consecutive winters (2019-2020 and 2020-2021).

The occurrence of the Hazel Grouse was searched by intensive prospection of indirect signs of presence mainly droppings and tracks in the snow during favourable snow and weather conditions. The surfaces of the prospected sites varied between 5 and 110 ha, with an average of 33 ha. The precise definition of prospected areas was either directly driven by a previous knowledge of the site or oriented by vegetation characteristics known to favour Hazel Grouse occurrence (dense understory of resinous trees mixed with broad-leaved bushes used as staple food in winter).

Results

107 prospections were carried out by trained observers (one to 10) in the 69 predefined sites. Most of them were visited once (n=49). The others were respectively visited 2 times (n=14), 3 times (n=3), 4 times (n=2) and the last but not the least site was checked 13 times.

The presence of Hazel Grouse was detected on 10 visits (9.7%), and only on 6 sites, i.e. 9% of the total. Only three direct sightings were obtained of single flushed birds, and none of them could be associated with the presence of a pair.

To take into account imperfect detection and to estimate the detection probability, we used the data from the 18 sites which were visited at least twice. Nine among 20 repeated visits were positive leading to a rough estimate of 0.4. In application of Bayes's rules of conditional probabilities, we estimated that nine sites, at most, could be actually occupied among the 49 sites visited only one time.

Conclusion

This work confirmed that the Hazel Grouse is in the verge of extinction in the Vosges Massif. Owing to this long-term decline which seems to have accelerated over the last decade, we predict that complete extinction will likely occur in a decade or two.

Although the absence of randomisation in the process of site selection could give biased estimated of occurrence, it is nonetheless doubtful that a numerically significative population might go unnoticed. Indeed, the Vosges Massif is a highly developed area with a dense network of trails and forest roads which make all parts accessible. Despite large forest patches (tracks), only a low proportion of good Hazel grouse habitat remain, consequence of a long history of intensive forestry. So, the prospected area may constitute a rather high part of potential occupied areas.

To give weight of this pessimistic prediction it is significant to mention the disappearance of the Hazel Grouse in the neighbouring Black Forest in Germany which presents numerous similarities. In this massif, only 50 occupied sites were known in the beginning of the 1990s (Asch, 2007), but even with a massive and positive change in forestry practices from this time (Handschuh & Birk, 2019), the last observation was in 2004. Presumably, at this time the population size was still too low to allow the population recovery, and this work suggest that Vosges population has now also crossed this threshold.

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The habitat uses and behaviour of Black Grouse (*Lyrurus tetrix*) in western Norwegian heathlands, in winter

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Abstract

Human activities keep exploiting lands to the detriment of biodiversity and species that are declining, owing to this habitat loss. Hence, understanding what use a species makes of its habitat contributes to preserving the species by establishing conservation strategies. Black grouse has a huge distribution range, from the Atlantic coast and northern Eurasia to south-eastern Siberia. Therefore, the majority of their distribution area has large climatic variation between summer and winter. Most studies on black grouse winter behaviour describe inland populations, whilst the habitat use of coastal populations is poorly described. We studied the habitat uses and winter behaviour of a coastal population of black grouse (*Lyrurus tetrix*) during winter 2021-2022 in the heathlands of Lygra, a coastal island in western Norway. We quantified vocal territoriality and the use of heathlands as feeding grounds during winter. We find that black grouse are present in the heathlands on the island through winter to mark territory and to feed. We used an acoustic recorder and recorded two types of calls, hisses and coos, proving that this coastal population of black grouse vocally defends their territory in winter, in contrast to inland populations. Black grouse appear to be most active shortly before and up to two hours after sunrise. No vocal activity is found in the afternoon or before sunset. We notice a decrease in activity from December to January, which may be due to increased rainfall and wind. Black grouse keep singing during both positive and negative temperatures but tend to reduce activity at very low temperatures. Fecal analyses confirm that they feed on the heathland shrub *Calluna vulgaris* in winter, and we did not observe any changes in their diet over the winter period.

Introduction

According to the 2019 report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, three-quarters of the global land-based environment has been significantly altered by human actions (IPBES, 2019). This land-use change can be the conversion of land cover, changes in the management of the ecosystem or agro-ecosystem, or changes in the spatial configuration of the landscape (IPBES, 2019). Therefore, it damages, divides and wipes out habitats to meet human needs and preferences. As a result, land-use change is the main driver of biodiversity loss worldwide and even species extinction as they lose their habitats (IPBES, 2019). Hence, a crucial part of restoring, conserving and managing species is to understand the habitat use.

The black grouse (*Lyrurus tetrix*), (Linnaeus, 1758), is a bird whose habitat has been altered for decades now. The species is widely distributed globally: ranging from Britain and North Eurasia to China (Lawrence, 2004; Zhang et al. 2020). Studies of Wegge & Kastdalen (2008) and Ciach (2015) showed that black grouse avoids dense woodland. The northern population is rather associated with young forest (Swenson & Angelstam, 1993; Gregersen, 2009; Ciach, 2015) or forest edge habitat (Paloc, 2004; Wegge & Kastdalen, 2008; Kurhinen et al., 2009), but coastal populations are also found in open heathlands (Baines, 1994; Starling-Westerberg, 2001). The differences in habitat use and winter behaviour between the inland and coastal populations is poorly described, but there are reasons to expect that there are important differences between these populations, in terms of habitat use and winter behavior. We expect these differences to be especially clear in winter, because of the lower temperatures, more snow cover, and higher predator pressure in the inland compared to the coastal areas.

Black grouse territoriality involves competitive behaviour such as calls and physical confrontations (Brown & Orians 1970). Studies on territorial behaviour is focused on inland populations and are concentrated on activities performed in spring, during the mating season (Rintamäki et al. 1999) when seasonal cackle period doubtless concurs (Kruijt & Hogan, 1967). Females may also show territoriality during the breeding season (Angelstam et al. 1985). Yet, males can have territory defence behaviour in autumn (Rintamäki et al. 1999) and visit leks most of the year (Gregersen, 2014, in Eastern Norway). According to Gregersen (2014), males fight for a position in the flock each day to establish dominance hierarchies. Black grouses also have a largely herbivorous diet (Lawrence, 2004). The diet of inland populations of black grouse consists of leaves and buds of berries, rowans, alders, spruces, and some seeds (Starling-Westerberg, 2001; Darmangeat & Dupérat, 2004; Paloc, 2004) and needles from resinous trees and bilberries (*Vaccinium myrtillus*) (Wegge & Kastdalen, 2008; Selås, 2019). Specific descriptions of the coastal populations' diets are lacking, but high availability of rather notorious shoots of *Calluna vulgaris* suggest that this is a relatively more important plant in the coastal populations' winter diet compared to inland populations.

Therefore, the interest of our study was to know more about winter behavior and habitat use (feeding and territoriality) of a coastal population of black grouse in western Norway, focusing on their diet and calls. This would highlight differences with inland populations of black grouse. So, based on frequent observations of black grouse in heathland habitats during winter, we recorded sound at dawn and dusk through winter to explore if the males were expressing territorial calls in a coastal black grouse population. We also studied plant material in feces samples to quantify how important heathlands are for feeding and foraging through winter, and to determine if the diet varies from early to late winter.

Material & Methods

1. Black grouse

We studied a coastal population of black grouse (*Lyrurus tetrix*) in Norway from December 2021 to February 2022. The population size has not been quantified, although observations of 15 males simultaneously (artsobservasjoner.no) suggest a population size of at least 30 individuals (Ellison and Magnani 1985, Marti et al. 2016). Despite the species being ranked as 'Least concern' on both the IUCN and the Norwegian red list for species, the species is nowadays in decline, and has even gone extinct in some distributional border areas (Warren & Baines, 2002). The driving causes for the decline are intensified land-use, climate change, parasite infestation, and predation (Baines et al., 2000 ; Ciach, 2015 ; Jahren et al., 2016 ; Hambálková et al., 2021). Moreover, the reproductive success of the species has also decreased (Ciach, 2015; Jahren et al., 2016). According to Gregersen (2009), a decline in the Norwegian black grouse population has been observed since 1970, especially into the south and in the very north of the country.

Black grouse are most active in the early morning and spend the rest of the day, 94 percent on average, hiding (Marjakangas, 1992 ; Darmangeat & Dupérat, 2004). Black grouses show their territoriality with actual defence (attacks, chases) but also with calls and displays that keep rivals out (Brown & Orians 1970). As Angelstam (1985) described it, "the cackle-call is used as an identifying territorial act and as an aggressive call in actual defence".

2. Study site

The study site is located at Lygra (Figure 1), an 2.5 km² large island in Alver municipality in western Norway. Most of the island is covered in agricultural land, ranging from semi-natural heathlands in the northwest to more intensive land-use in the central part, and afforestation in the southeast. Approximately 60 people live in the central part of the island. The heathland is about 0,5 km² and reaches up to 20 meters above sea-level. Vegetation is dominated by common heather - *Calluna vulgaris*. There are also bushes and shrubs. The heathland is grazed year-round by old norse sheep.

Coastal heathlands are amongst the oldest cultural landscapes in Europe, reaching back 6000 years (Gjedrem & Log, 2020). Today, coastal heathlands have high conservation value throughout their range because of their biological diversity and cultural history. While the heathlands along the European Atlantic coasts are threatened by extinction - as much as 90 percent of European heathlands have been lost in the past 100 years due to cultivation, pollution, and overgrowth (Kaland & Kvamme, 2014) - authentic heathland coastal landscape of Lygra are well preserved, as it is a museum and research station used all year round. They are maintained by local farmers through periodical burning and continuous grazing. Once a year, prescribed burning is applied to parts of the heathland, creating a mosaic of fire patches with a fire return interval of approximately 25 years across the landscape (Figure. A1 in the appendix). This mosaic burning maintains fodder value of the vegetation and increases species richness through high microscale vegetation heterogeneity. The periodic burning and year-round grazing are not believed to affect black grouses directly, however this management is necessary to keep heathlands open and provide the habitat where black grouses can find food (heather, bilberry, buds, leaves) and display in open areas (Figure. A2 in the appendix).

Figure 1. Location of Lygra, the island with heathlands outlined in red. Source : Google Maps, 2021. Location of Lygra. Google Maps.

3. Audio recordings

We used an acoustic recorder (Song Meter Mini from Wildlife Acoustics) to quantify territorial behaviour of black grouse in the heathland from December 2021 to the beginning of February 2022.

The recorder possesses an omni-directional microphone, has a recording bandwidth from 20Hz to 48 kHz and can run 210 scheduled hours. These characteristics make it very suitable for bird recording. We placed it in a suppression in the terrain to shelter it from strong winds (Figure 2), close to a hill with frequent observations of black grouses, in an early-successional stage of heathlands. The frequent visits to this hill were confirmed by the presence of fresh black grouse feces. The recorder is fixed high up on a wooden post so as not to be disturbed by the sheep. We programmed it to start recording from 7:00 to 11:00 and from 13:30 to 18:00, to capture the time just before and after sunrise and sunset. Every two or three weeks (dates in the appendix), we collected the recordings from the SD Card and changed the battery. Thus, this method is easy to implement, inexpensive and allowed us to study black grouses with little interference in their environment.

Figure 2. Location of the recorder in the heathlands. Source : Google Maps, 2021. Location of the recorder in the heathlands. Google Maps

Then, to analyse the collected recordings, we used the version 2.3.3 of Audacity® recording and editing software [1]. It gives the spectrogram that enabled us to simply "look" for a sound through visualizing the audio recordings (method in Figure A3 in the appendix). We knew the shape of a black grouse sound, thanks to literature (spectrograms in the study by Hambálková et al. (2021), Xeno-Canto website (spectrograms and audio recordings) and by recognizing the sound during our analyses. A spectrogram also provides complementary information like frequency, intensity and duration of the sound. Figure 3 illustrates an example of a spectrogram representing the audio recordings from two types of black grouse calls. Figure 3a shows a hissing call. This sound has a wider range of frequencies, often is shorter in duration and it is composed of two notes. Figure 3b illustrates a cooing call (Kruijt & Hogan, 1967). This sound has a smaller intensity, a lower and smaller frequency range, and may last longer because it is composed of several notes as it is a coo, a cackle. One repetition of each sound is visible.

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[1] Audacity® software is copyright © 1999-2021 Audacity Team. The name Audacity® is a registered trademark.

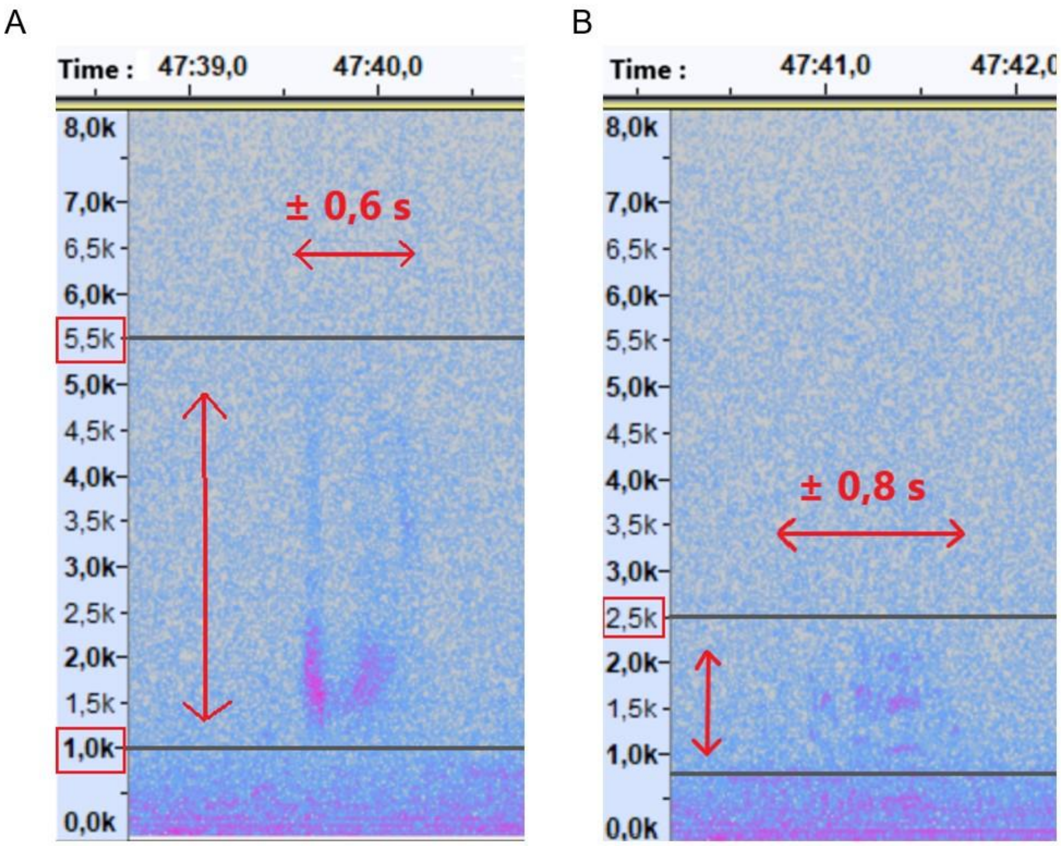

Figure 3. Two sounds produced by a black grouse. A: hissing call. B: cooing call. The horizontal and vertical axes represent time and frequencies, respectively. The horizontal and vertical red arrows represent respectively the duration and the frequency range of the sound.

For all of the calls found on the spectrograms, we noted the date, the time of day and the time in the recording in which it occurs and specified the type of call. We counted and sorted them. To obtain the length of activity, we defined a period of activity as calls with less than one minute of silence in between. Then we calculated the sum of the periods of activity per day, during recording hours.

We also used weather data from the study period, collected by the bioCEED weather station at Lygra to answer if the activity is affected by temperature, precipitation or wind. First, we summed the amount of precipitation, per day, from 6:00 to 11:00, so it would correspond to the period where black grouse sing, and we looked for the maximal wind speed over the same time slot. Then, we calculated the average temperature, still between 6:00 and 11:00.

4. Faecal collection and analysis

In order to determine the diet of black grouses, to know if it changes during winter and to explore if black grouse also use the heathlands for foraging, we collected their feces. We collected it twice, around ten samples each time, at the end of November and in January to compare feces from the beginning and the end of winter. Each time, samples were collected (Figure 4a) in two areas where black grouses are frequently observed during winter. Both areas are in the young successional vegetation stage of heathlands, meaning that there is less than 7 years since the last fire. One of the areas is a natural hill, whilst the other area has scientific installations with dimensions 3x3x1 meter (length x width x height) which black grouses have been observed to use for displaying. Then, in the lab, the samples were dried in the oven, weighed with a fine scale balance and placed in petri dishes before being fragmented with forceps and fingers. We looked for recognizable fragments of branches, seeds and leaves. We sorted them in smaller petri dishes (Figure 4b) and weighted these portions. Thus, we calculated the ratio of their mass to the total mass of the sample and obtained the proportion of branches, seeds and leaves in the black grouse diet. But we also had to consider the part of the samples which remained unsorted, due to the tiny size of the fragments, to properly interpret the results. Indeed, the variations in identified sample proportions may have been caused by varying degrees of fragmentation of the plant matter in each sample. For that, we calculated the ratio between the mass of sorted matter and the total mass of the sample. Moreover, the results will be discussed as approximations and not as a direct measurement, because much of the leaves could have been digested already. When the grouse feeds on a plant, it eats a whole section of the shoot, which is a branch covered in leaves.

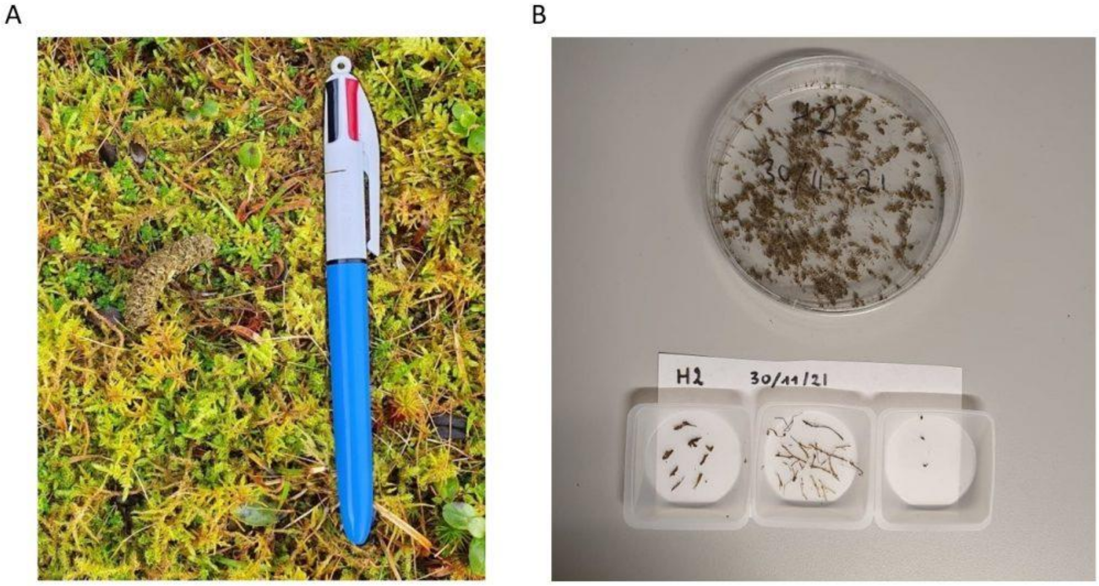

Figure 4. A: Collected feces. B: Sorted and dried fragmented feces

Results

Acoustic analysis

Spectrogram

Our acoustic analysis reveals the existence of black grouse calls in the heathlands in winter. We heard two types of calls (Figure 5a) : cooing calls within a range of 900-2500 Hz (Figure 5b) that often overlaps with background noise frequencies, and hissing calls (Figure 5c), with wider signals in the frequency range of 1000-5000 Hz, sometimes up to even higher frequencies, depending on the intensity of the call. With these frequencies and the fact that they often are louder than coos, they are easier to filter out from background noise. We heard both isolated and grouped calls.

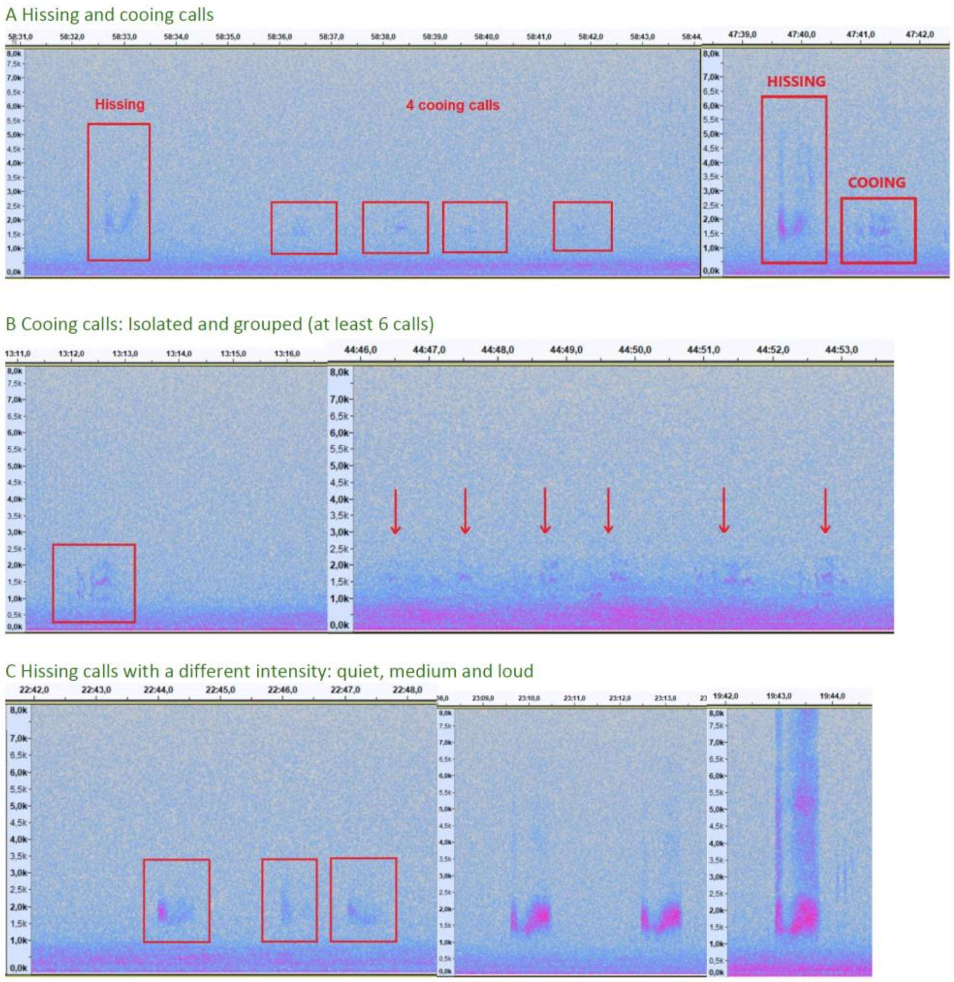

Figure 5. Spectrograms showing the different calls of the black grouse.

Timing of calls

Calls counting per time slot: Over the entire recording period, we never heard black grouse calls in the afternoon between 13:00 and 18:00. The results show that black grouses sing during our morning recording session that is between 7:00 and 11:00. The peak of activity comes between 8:00 and 10:00 (Figure 6), that is just before and after sunrise that happens between 8:30 and 9:30 from December to February. It also demonstrates that it is the same pattern for the two noises.

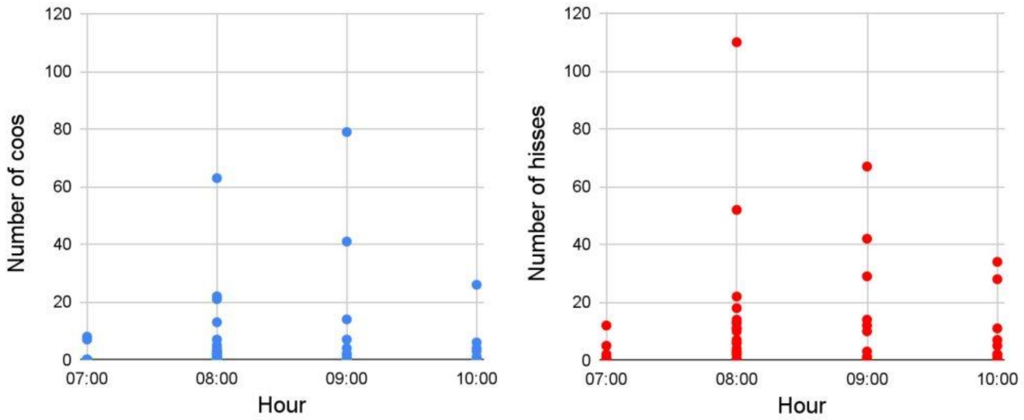

Figure 6. Number of coos and hisses recorded per day, according to the time slot. A dot represents one day.

Total number of calls and inactive days counting: We recorded 597 hisses and 362 coos, during our study period. We do not have continuous recordings due to the batteries running out that make us miss some days. In December, the maximum number of calls heard was 110 hisses and 79 coos against 12 hisses and 8 coos in January. No calls were heard during 6 days over 21 days of recordings in December and during 16 days over 20 days in January. That is, in December, 28 percent of the number of study days were without audio activity and 80 percent in January. Over the entire period of study, 43,5 percent of the days recorded audio activity. The overview of all the calls recorded is in Figure A4 in the appendix.

Length of activity: By taking all the days of recording into account, the average length of activity is 179 seconds so almost 3 minutes (Figure 7). By taking all the days where at least one song was heard (the "active days"), the average length of activity is 412 seconds (6 minutes and 52 seconds).

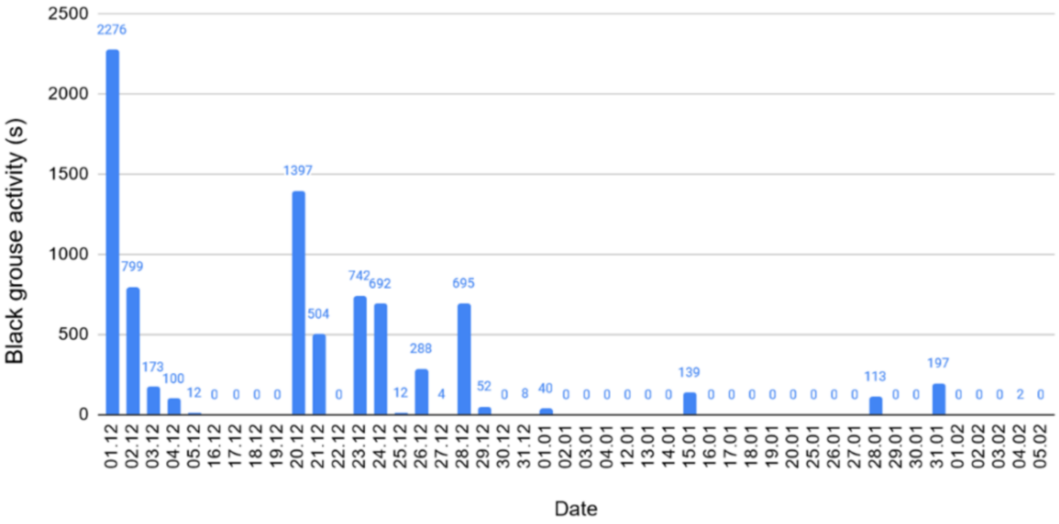

Figure 7. Length of black grouse activity in seconds per day. Some dates are missing due to data gaps in the recordings.

Weather data

By comparing the days with black grouse activity with the other days, we detect a trend: the length of activity of black grouse is more important when precipitation is low and the wind quiet (Figure 8). For example, on December 1, there was apparently no rain, the wind was light and back grouse activity was over 2000 seconds, whereas during the first half of January, when the weather was rainy and windy, there was no black grouse activity. We however point out the absence of some data recordings from the weather station on January 29 between 10:00 and 11:00, on February 2 (all day) and on February 3, from 6:00 to 10:30. Thus, on Figure 8, the weather values of these days may be higher because they are incomplete.

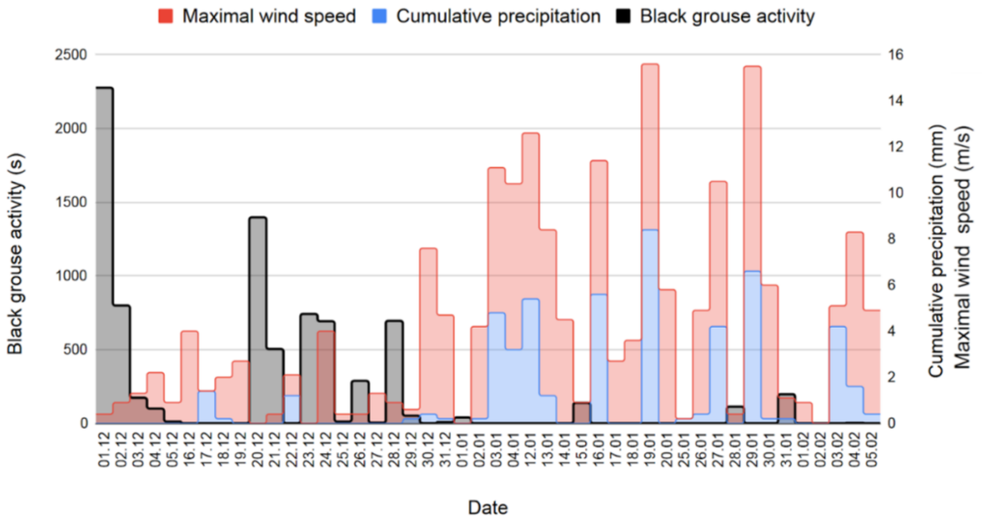

Figure 8. Length of black grouse activity and sum of precipitation and maximal wind speed per day. Precipitation and wind areas are stacked.

We find recorded calls during both positive and negative temperatures (Figure 9). For example, on December 24, the average temperature was -1.8°C and black grouse activity was around 700 seconds. On January 15, the average temperature was 2.5°C and black grouse activity was around 200 seconds.

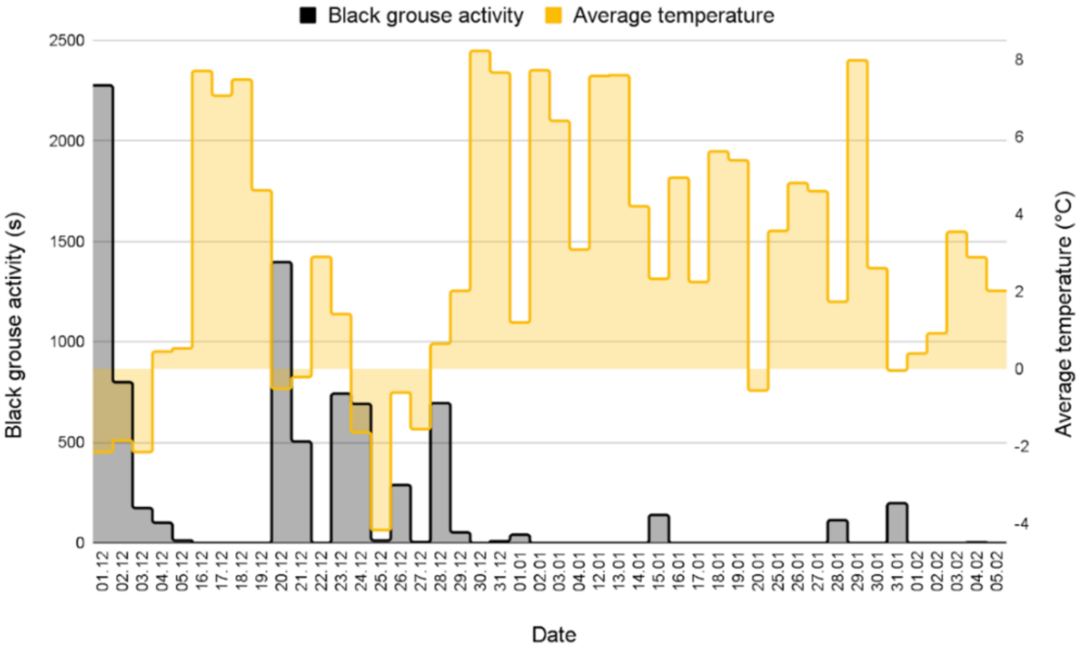

Figure 9. Length of black grouse activity and average temperature per day

Diet linked to the surrounding vegetation based on collected feces in the heathlands

At first sight, fecal samples from November 30 and January 25 have a similar texture, color and when sorted, similar fragments. The composition consists of branches and leaves of *Calluna vulgaris*, and some seeds, for these two groups of collected feces. Branches often represent between 0 and 10% of the sample, except for sample 1 and 7 (Figure 10a). But these values may be nuanced with Figure 10b, which shows how much matter was sorted over the total amount of the sample. For example, sample 1 has the biggest amount of branches but because it has probably been more sorted, given that the ratio sorted matter/non-sorted matter is more important. Therefore, there is little difference between November and January and branches were more often found than leaves and seeds. We did not find any seed in the fecal samples from area 2, a hill with scientific installations.

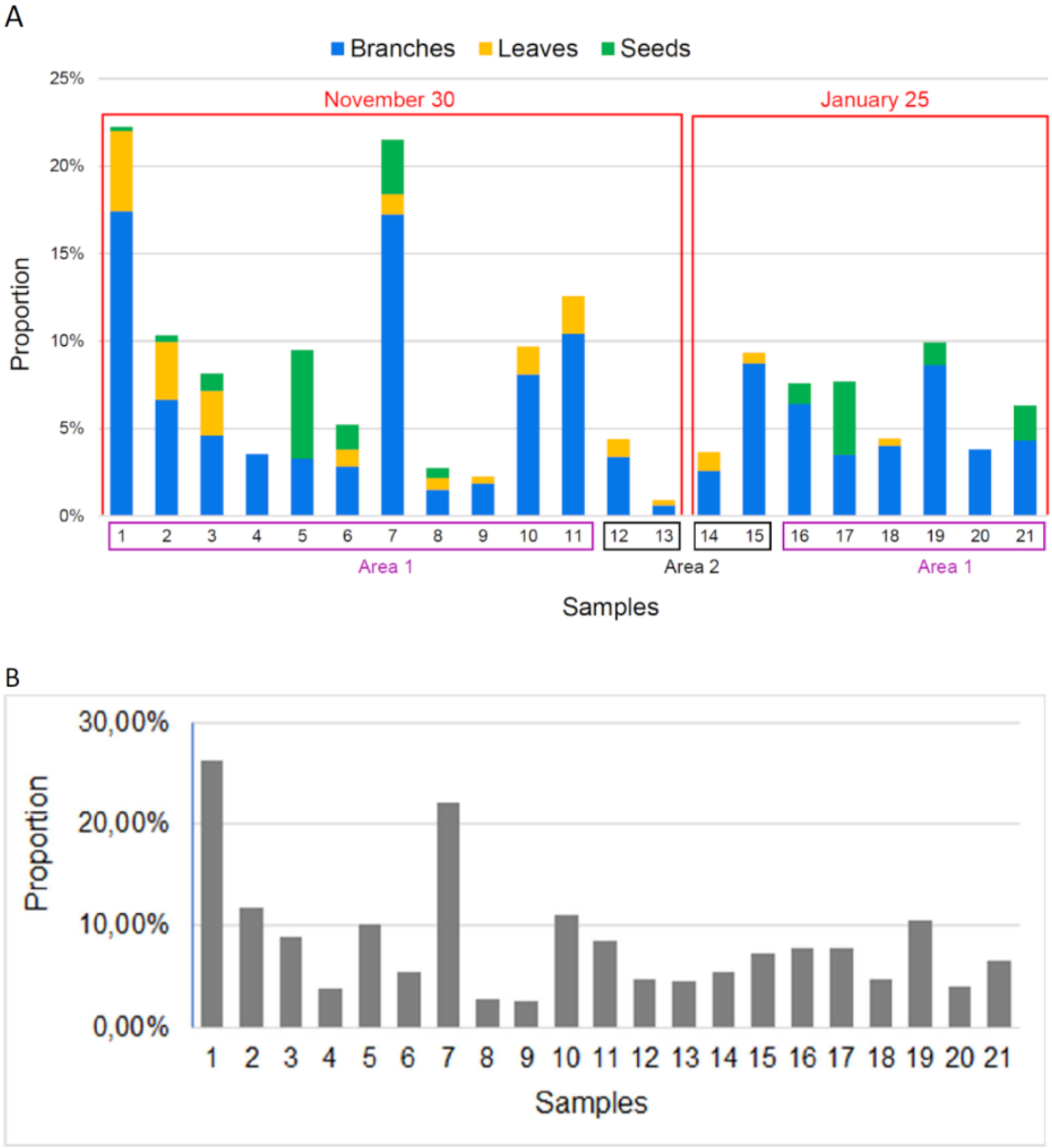

Figure 10. A: Proportion of branches, leaves and seeds in the sorted matter per fecal sample. B: Proportion of sorted matter per fecal sample. Area 1 : Natural hill. Area 2 : Hill with scientific installation.

Discussion

Location of black grouse on Lygra

On Lygra, the coastal population of black grouse lives in the open and this is the first difference in habitat use with inland populations. In winter, the latter can dig tunnels in the snow (Darmangeat & Dupérat, 2004 ; Paloc, 2004) that allow them to rest by being sheltered from cold (Bocca et al. 2013) and predators such as, red fox *Vulpes vulpes*, golden eagle *Aquila chrysaetos* , pine marten *Martes martes* but mainly the northern goshawk *Accipiter gentilis* in forest. These predators are common in forest/inland areas compared to coastal/open areas. However, there are some foxes at Lygra. Then, as black grouse hide in the bushes and shrubs on Lygra when they are not displaying or foraging, it is probably an anti-predator strategy, as it is a common strategy in many other birds.

According to Angelstam et al. (1985), cackle-calls could be located from about 600 m, or even from 1 km in open terrain according to Boback & Muller-Schwarze (1968). So, knowing the location of the recorder, we draw circles of 600 and 1000m radius (Figure 11). They cover the study area and certify that the black grouse heard are found in the heathlands.

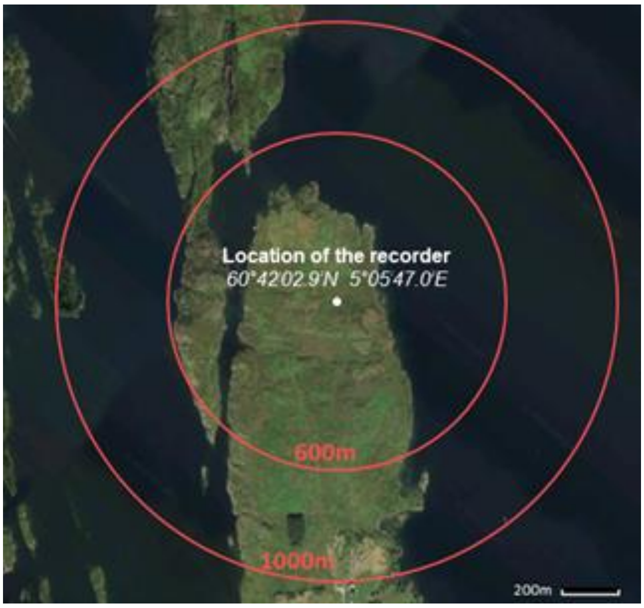

Figure 11. Distance from the recorder, represented by the red circles. Source: Google Maps, 2021. Distance from the recorder. Google Maps].

Winter behaviour

Territoriality through calls

The literature of Norwegian black grouses is mainly based on inland populations who live in the forest all year. It is described that males have a strong territoriality in spring and cackle calls start three weeks before the beginning of incubation, late April (Angelstam et al. 1985), or that males and females show fighting behaviour and territory defence in autumn and in spring (Rintamäki et al. 1999). We heard hissing and cooing calls. Then, this study indicates that this coastal population of black grouse show territorial behavior during winter. Indeed, as mentioned before, territoriality is shown through calls that can be described as aggressive calls (Cramp, 1983). Especially hissing calls, that are frequently uttered during threatening, flutter-jumping and fighting (Kruijt & Hogan, 1967).

Our data match with the study of Hambálková et al. (2021), in which they found call frequencies from 352 to 4482 Hz for black grouse populations of Finland and Scotland. Yet, with our analysis, we cannot exactly tell if black grouse calls frequencies fall below 900 Hz as it is mixed with background noises.

Winter activity

As for studies before (Angelstam et al. 1985; Kruijt & Hogan, 1967; Marjakangas, 1992), our results show that bird territorial activity is confined in the morning. We did not notice evening activity unlike Hjorth (1970) suggested. The daily total cackle period in winter is around three hours. That concurs with the study of Angelstam et al. (1985) and Marti and Pauli (1985).

Even though black grouse are out and singing in winter, they seem to be less active in January and February. The length of activity is below ten minutes and depends on the weather, especially precipitation and wind. On rainy and windy days, black grouse stay hidden and do not sing. Black grouse also tend to reduce their activity at low temperatures (Keller et al., 1979). According to the study of Marjakangas (1992), length of activity is correlated with ambient temperature but not with photoperiod.

Characteristics of the calls

The two types of calls that we were able to hear are defensive calls. Black grouse seem to use more often hissing calls over coos. Moreover, there is no hour difference between coos and hisses, both songs follow the same pattern.

Foraging and feeding

Black grouse inhabit the heathlands where they can find resources necessary to them. Studies often describe the winter diet of inland populations of black grouse, living in the forest where snow covers the floor (Bocca et al. 2013). Because of snow cover, these birds are forced to feed in trees and taller shrubs, so mountain pine needles or buds of many conifers are found in their diet (Bocca et al. 2013). But Lygra is not often covered by snow and the vegetation in the heathlands differs. The results of this study suggest that the common heather *Calluna vulgaris* make up most of the diet of the black grouse population at Lygra, as stated in the study of Baines (1994). During winter, their diet does not seem to change. Moreover, as Marjakangas (1992) deduced, if black grouse are only active in the morning, it is probably during this period that they feed. And because of the relatively low nutritive value and digestibility of their diet, they must feed regularly, because they do not accumulate substantial fat reserves (Bocca et al. 2013). This low digestibility explains that we were able to sort the samples and find recognizable fragments of branches, leaves and seeds.

Improvement ideas for our recording analysis

Margin of error: Even if the recorder is very good, strong wind and rain have been an issue for the acoustic analysis. It creates more background noises and even large signals and makes it more difficult to hear and see calls (Figure A5 in the appendix). Therefore, one possibility is that we may have missed some calls during bad weather. The second possibility is that during bad weather, black grouse stay sheltered and do not sing anyway so we did not miss any call. Also, some cooing calls may be missing because, due to their low frequency range, they are barely visible and mix with background noises (Figure A6 in the appendix). We also had to ensure to differentiate black grouse songs from other birds (Figure A7 in the appendix).

*Battery run-time and SD Card capacity***:** To avoid periods without any recording due to dead batteries or lack of space on the SD Card, we should have checked the recorder more often at the beginning of our study.

*Recording hours***:** Some days, calls were recorded on the 10am recording, between 10:30 and 11:00 and even at 10:59. A quarter of the total days of study contain calls between 10:30 and 11:00. Therefore, it seems that black grouse can sing late in the morning and it can be interesting to add one or two more hours in the recording session, that is from 7 to 1pm. Moreover, we were not able to know how many black grouse we heard during the audio analyses.

Conclusion

On Lygra, the coastal population of black grouse uses the habitat for roosting, marking their territoriality and foraging. The heathlands are then vital for them whereas inland populations inhabit forests and clearings. These coastal black grouse keep their territorial behavior through calls, to a higher degree than inland populations. They show morning activity that decreases during winter and depends on the weather, especially precipitation, wind and temperature. They feed on branches and leaves of *Calluna vulgaris* and seeds, and their diet does not seem to change during the winter. Knowing this information, is important in terms of species management. To go even further in this approach, it would be interesting to correlate the presence of black grouse in Norway with the conservation of Norwegian semi-natural landscapes and ecosystem services.

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Non-invasive monitoring of Western Capercaillie brooding activity with camera traps shows promise in Scotland.

Jack A. Bamber, Kenny Kortland, Chris Sutherland, Ana Payo-Payo, Richard Mason and Xavier Lambin.

Introduction

The plight of capercaillie *Tetrao urogallus* in Scotland has been well documented, with recent estimates suggesting a second extinction may be likely, with current estimates predicting 580 birds in 2020, a reduction of more than 50% from estimates in 2016 (Wilkinson et al., 2018; Robertson, Costanzi and Ball, 2020; Baines & Aebischer, 2023). This places them on the British “Red List” of protected species, indicating the need for further conservation action and intervention (Eaton *et al.*, 2015). Robust monitoring of productivity is vital for understanding population trends and for quantifying the effect of a management interventions on recruitment. Traditional monitoring methods for productivity include flushing broods using dogs, human-led walked transects, or tracking hens with radio telemetry (Summers, Dugan and Proctor, 2010). These are all invasive methods and present a likelihood of reduced fitness and mortality for chicks and adults, through stress and abandonment (Moss *et al.*, 2014) and direct harm. Paired with the rarity of these birds in Scotland, several land managers have ruled out monitoring of broods via dog counts, and, as a result, critical productivity monitoring is now lacking. It is, therefore, vital for capercaillie management in Scotland that non-invasive monitoring methods are explored.

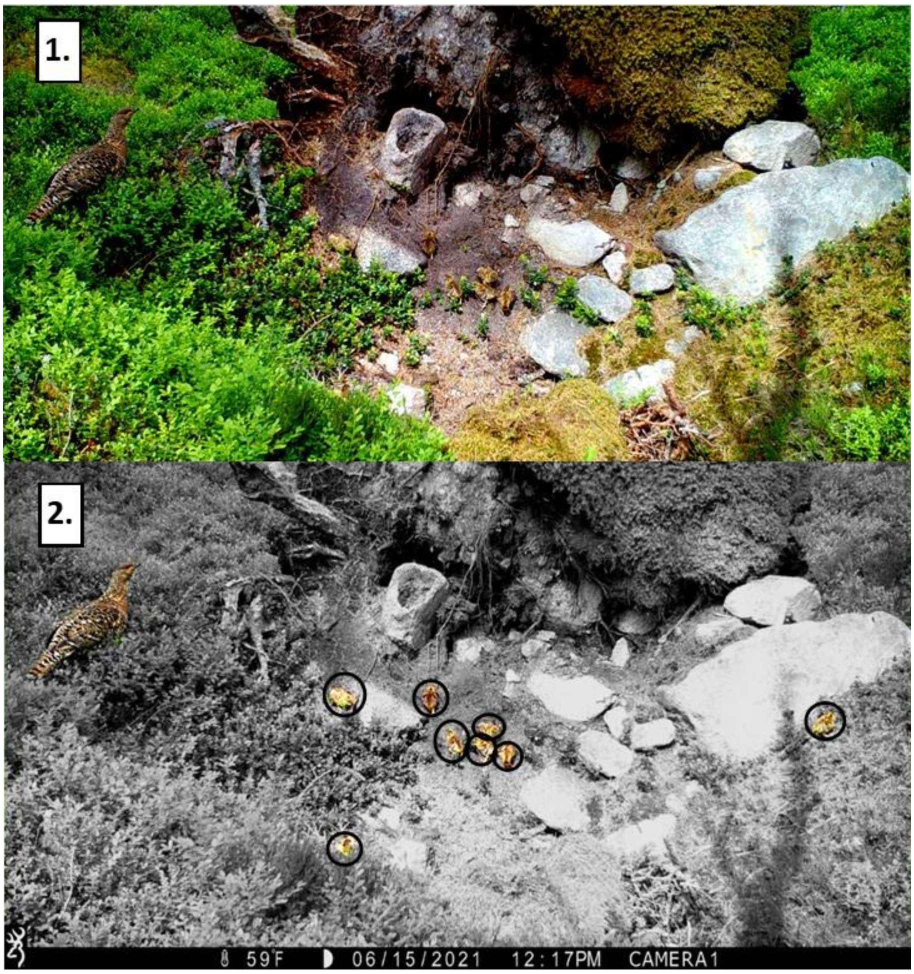

Figure 1. Brood image and chick counting. Image 1 shows the original capture, collected via camera trapping, showing the upturned root plate alongside the hen and brood. Image 2 shows the same image, with colour editing, the chicks and hen have remained in high contrast colour, with the background in black and white and sharpness increased, to improve clarity of observation. All chicks visible have been highlighted by a circle. We were able to identify eight individual capercaillie chicks; expected chick counts are estimated to be ~7, based upon the average number of eggs laid in a clutch, ranging between 6-10 (Summers, Willi and Selvidge, 2009).

Previous work noted in Grouse News ((Stephani et al. 2014)) and evidence seen on YouTube, indicated that capercaillie broods may be detectable at dust bathing sites, providing thinking that a large-scale camera trap deployment may allow brood detections without the need for dogs.

Premise

Dusty and gritty areas are known to be a valuable resource for many bird species, with dust bathing providing parasite removal, cleaning, and preening (Olsson and Keeling, 2005, Downs, Bredin and Wragg, 2019). Making these sites a suitable focal point for camera trap deployment, similarly to how forest tracks are often used for predator camera trapping, due to regular usage (Rowcliffe and Carbone, 2008). We also placed cameras in 2021 on wet features and open cleared ground (felled rides), but only dust baths were effective in detecting broods.

Camera traps (Browning, Recon Force Advantage) were set within 30, 1km^2 sample grids across multiple estate partners. Selection of sites was primarily, in brood habitat (Scots Pine *Pinus sylvestris* forest, with a rich Bilberry *Vaccinium myrtillus* under-storey), within areas of known capercaillie activity, based on lek sites and historical data on brood counts. Cameras were focused on micro-sites with exposed soil such as upturned root plates and banking. The locations selected had clear indications of recent use, i.e., recent dust baths, and capercaillie droppings or feathers found locally.

Figure 2. Mature Poults detected at a dust bath, males and females are easily distinguished due to the black plumage of males and the brown mottled plumage of females.

Early Successes

Capercaillie broods have now been captured on multiple camera traps across a two-year sampling period, detecting broods at differing stages in their life cycle. Deployment produced 15,000 images, containing capercaillie, from 150 camera traps, with a capercaillie (Male, Female or Brood) being detected at 57% of camera traps. Repeat detections at sites, and monitoring over an extended period, indicate an ability to monitor brood depletion. Chicks and hens are often clearly identifiable in images, allowing minimum counts of chicks and poults could be established easily as seen in Figure 1. Alongside this, images later in the season (when plumage has come in) allow observers to identify the sex of the poults effectively, again a useful metric when establishing life history traits of capercaillie for monitoring and population estimates (Figure 2). Behaviour of broods is also detectable at these sites (Figure 3). This shows a brood of six young chicks using the dust bathing area, following their mothers. The brood enters the root plate whilst the hen is present, but after she appears to have finished bathing, and leaves, the chicks remain for >3 minutes (Figure 1). This sequence of events is interesting and thought provoking as it shows what we believe are un-noted brood behaviours of both chicks and hens.

Collectively this is a positive indication that dust bath camera traps could be a robust method to replace dog counts in producing productivity estimates, whilst simultaneously providing further nuance into brood structure and behaviour, as well as opportunistic detections of other species using the same areas (including possible capercaillie predators). Whilst this is particularly relevant to the Scottish system, where dog counts are reduced, application is likely broad reaching, to assess and evaluate capercaillie in other parts of their home range where they are in decline. We will continue to trial this method and make further assessments on the insight this method provides for monitoring and conservation.

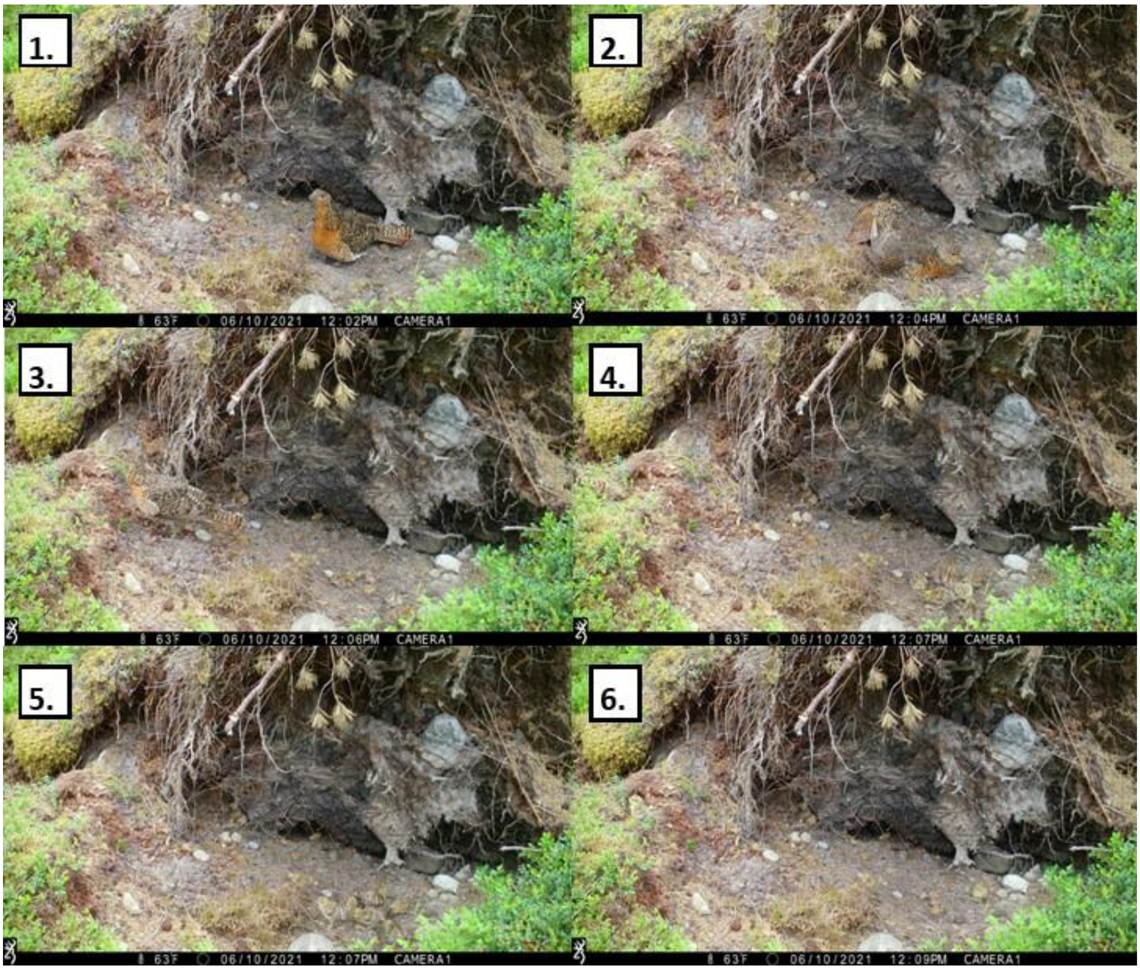

Figure 3. Common Sequence of brood activity, following from top to bottom. 1.Hen enters dust bath area, alone. 2.Hen dust bathes and consumes soil. 3. Chicks begin to enter root plate area, hen leaves. 4. Chicks explore root plate; dust bathing can be seen to be performed by chicks. 5. Chicks leave dust bathing area. Seven Minutes of total activity from first image of hen to final image of chicks.

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CONFERENCES

15th International Grouse Symposium Białystok Poland 11-15 September 2023

We cordially invite you to participate in the 15th International Grouse Symposium, which will be held in Poland, in Bialystok on September 11-15, 2023 hosted by University of Białystok (UwB). The 15th IGS is co-organized by three institutions: University of Białystok, the Polish Academy of Sciences and Directorate of Polish State Forests in Białystok. Białystok is the largest city of North-East Poland, with a convenient connection from Warsaw by car or a fast train (2.20 h. ride). The Symposium will be held at the brand-new Campus of University of Bialystok.

We are pleased to introduce the invited speakers at the 15th International Grouse Symposium:
Agnieszka Kloch, Associate Professor on the Faculty of Biology at the University of Warsaw.
Host-parasite co-evolution with a focus on the role of parasites in shaping host genetic variance in birds
Robert Moss was associated with the Institute of Terrestrial Ecology in Scotland for many years.
Climate change and human-grouse interactions
Sara J. Oyler-McCance, research geneticist with the U.S. Geological Survey (USGS) at the Fort Collins Science Center (FORT).
Conservation genetics and population management in grouse
Gail L. Patricelli, Professor in the Department Evolution and Ecology at the University of California.
Behavioral ecology and conservation in grouse
Robert Rutkowski, Associate Professor at the Polish Academy of Science.
Biodiversity and conservation genetics of Tetraonidae in Poland
Ilse Storch, Professor and Chair of the Department of Wildlife Ecology and Management at the University of Freiburg.
Grouse ecology and conservation, population management

We also would like to offer you workshops on the 11th September, 2023:
"Sound recording and analysis workshop"
For more information please visit the website:
www.igs2022.uwb.edu.pl.

For enquires please contact the members of the Local Conference Committee of the 15th IGS: Aneta Książek and Dorota Ławreszuk:
igs2022@uwb.edu.pl.

Please remember IMPORTANT DATES:
- **31/05/2023** – submission of the abstract of presentations or posters
- **31/05/2023** – final acceptance notification (*ed. Date may be changed, check the website*)
- **30/06/2023** – registration of participants at Early Bird fees
- **30/08/2023** – completion of registration of participants – regular fees

PRACTICAL CONSERVATION FOR SCOTTISH GROUSE

Friday 5th May 2023

1000 – 1600hrs

Venue: Balhousie Castle, Perth PH1 5HR

WPA has joined forces with the Game & Wildlife Conservation Trust Scotland to hold a symposium entitled "Practical Conservation for Scottish Grouse Species" at Balhousie Castle, Perth on Friday 5th May 2023.

A line-up of expert speakers and commentators will examine each species (ptarmigan, capercaillie, black grouse & red grouse) in detail in the context of the challenges they face, both emerging and in the future, and the opportunities that we have and steps we must take to support their success or, indeed, survival.

The day will cost a modest £25, including coffees and lunch, thanks to generous sponsorship by Hampden & Co.

If you need to book accommodation on Thursday 4th May, several budget price rooms are available and can be reserved via the WPA office.

For more information and to book tickets, please contact Barbara Ingman on email office@pheasant.org.uk.

RECENT GROUSE LITERATURE

For a complete bibliography on grouse, go to: http://www.suttoncenter.org/about/publications/

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RESEARCHERS AND THEIR BEST FRIEND ASSISTANTS

The Return of a Friend

Bailey Petersen

When the snow melts every spring, I eagerly await the return of one of my favorite creatures. The American woodcock *Scolopax minor* is a small, ½ pound upland shorebird/gamebird, who makes her home in the densest tangles of brush, migrating back across the country to nest in the northwoods each spring. Usually returning very near to where they were hatched and raised the year before, they return in March from their wintering grounds in the south. This bird is loved by everyone who knows it. Bird watchers are drawn to its elusive nature and quirky habits such as bobbing and dancing across the road in hopes of rustling up an earthworm from beneath the soil surface. Bird dog enthusiasts value this species for how brave they are to rely so heavily on their camouflage to remain steady when stared down by our four-legged hunting companions. I once heard a phrase from a banding mentor that they valued the woodcock so much because “they honor the dogs”. It’s a funny thought, but if you’ve ever stared down the nose of a young pointing dog and spotted a timberdoodle deciding whether or not to take flight, it is a wonderful experience as the bird and dog seem to honor each other. A steady bird as a result of a steady pup.

I was introduced to woodcock banding before I knew much about either pointing dogs or our Minnesota woodcock banding program, which involves permitted banders and their well-trained & certified pointing dogs. Because of my newfound passion for woodcock banding, my training goal from the start for my first pointing dog, a small munsterlander named Mogul, was to get him prepared to be a banding dog. The Minnesota woodcock banding program puts a great emphasis on bird welfare so the training, testing, and continuous improvement protocols are fairly strict, as they ought to be for running dogs on public lands during the brood-rearing season. Banding dogs must be trustworthy, reliable, and proven steady to wing-shot-fall-release. This is critical because of the hen woodcock's behavioral adaptation to draw predators away from their young by feigning a broken wing or leg.

The spring woodcock banding season has been likened to a "catch and release" hunting season, with all the thrill of hunting but without harvesting the bird. The dog's job is much the same as in the fall, to find and point woodcock. But the human's job becomes much more complex; instead of rising visibly in front of you, your target lies small and camouflaged somewhere in the forest duff in front of you. To find them you must scour the forest floor for four tiny puffball woodcock chicks smaller in size than a golf ball. Don't take a step until they've all been spotted, as they blend into last fall's crispy leaves on the forest floor among the springs new growth. Once found, we can carefully scoop them up one by one and keep them safe in a bird banding bag while each chick gets measured and banded. Then all 4 chicks are released while the bander and their faithful banding dogs make a safe and quick escape to go search a new cover for another brood of woodcock. Banding data is submitted to the Bird Banding Laboratory in Maryland with the Fish and Wildlife Service where it is entered into the database with hundreds of thousands of other migratory birds banded each year. Woodcock chicks can fly within 12-14 days from hatching, so the woodcock banding season can be pretty short. Banding should only occur on days where weather is favorable, which leaves only a couple weeks each spring for this amazing experience.

For more information on Minnesota's Woodcock Banding Program, follow our social media pages for "Woodcock Minnesota" or please visit www.pineridgegrousecamp.com/woodcock-banding.
*The Minnesota Woodcock Banding Program is permitted by the USGS Bird Banding Laboratory to capture and band woodcock using certified pointing dogs.
See the link to the amazing Woodcock moonwalk: https://youtu.be/YF3-LvmHM4E.

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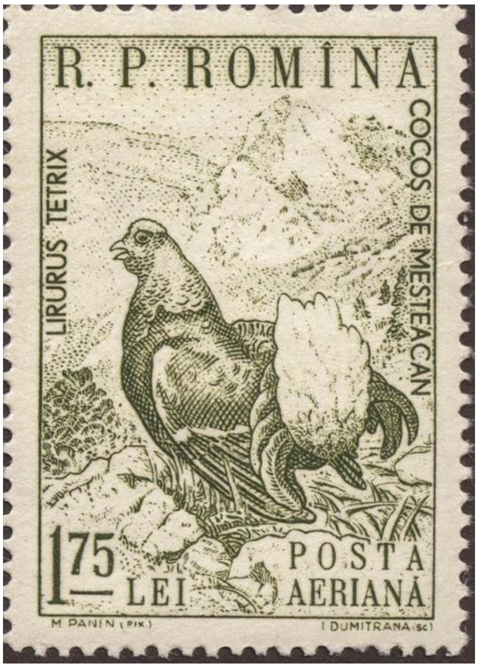
SNIPPETS

Grouse on Stamps

We started presenting stamps with grouse in issue 59 of Grouse News and presented 10 stamps. In this issue the second last stamps are published and the rest will come in the autumn issue. Please see issue 59 for more information. Ladislav Paule from Slovakia had the idea to present grouse stamps paule@tuzvo.sk.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Grouse News

Newsletter of the Grouse Group of the
IUCN-SSC Galliformes Specialist Group

What is Grouse News

Grouse News is a biannual newsletter of Grouse Group (GG) of the IUCN-SSC Galliformes Specialist Group (GSG) which is one of many specialist groups within Species Survival Commission (SSC) in IUCN. The primary function of this newsletter is to publish short papers and under way reports from research projects and conservation news. This will not prevent you from publishing in international review journals. Also short notes telling who you are and what you are doing is of interest. Information of upcoming conferences dealing with any grouse species and review of new books may be published. Also news from GSG and GG is published.

Interested in subscribing

When working with grouse you may be a member of Grouse Group (GG) of the IUCN-SSC Galliformes Specialist Group. To be a member you have to apply to chair of GG, Mike Schroeder, Michael.schroeder@dfw.wa.gov. As a member of GG you will receive Grouse News. You may also subscribe to GN without being a member of GG. The subscription is free. For subscription please contact chair of GG, Mike Schroeder, editor of Grouse News, Tor Kristian Spidsø, tks.grouse@gmail.com, or co-editor Don Wolfe, dwolfe@suttoncenter.org.

Writing in Grouse News.

If you do work on grouse you are welcome to publish your work in Grouse News. It may be a presentation of a new project or some of the results from finished projects. You may also publish news concerning conservation and management of grouse in your area. Even if you are not a professional grouse researcher, you may have interesting observations that may be of interest for others to read. So please don’t hesitate from sending contributions. All kinds of information are welcome.