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(Kopatz, 2019)

Can bears bear climatic change?

-A study of the impact of annual variation on the feeding behaviour of brown bears (*Ursus arctos*).

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Foreword and acknowledgements

I would like to thank the Scandinavian Brown Bear Project for their collaboration. Without their field-work – in which countless hours were spent dedicatedly collecting bear scat - this thesis would not have been possible. Thank you all for your immense efforts in collecting the data and providing me with unique insights into the world of the bears of Sweden.

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Happy reading!

Summary

Climate change is a topic of global importance, affecting species and ecosystems worldwide. Climatic variations and changes, like anthropogenic changes, have vast effects on plant-life, wildlife, and fungi alike. Nordic areas are especially sensitive, with temperatures in Scandinavia rising faster than in many other countries on earth (Walther et al., 2002). These changes can impact the quantity and quality of food items, potentially influencing life-history traits of animals living in the Scandinavian boreal forests. This could be particularly true for hibernating species, such as the brown bear (*Ursus arctos*). Before hibernation in late autumn, bears must increase adipose tissues for successful reproduction and survival during hibernation. The feeding behaviour of brown bears is likely to be impacted by climatic changes, as they rely heavily on berries, vertebrates, insects, and vegetative materials for survival.

In this study, a total of 352 scat samples were collected in a non-invasive manner, ranging from 2015-2019 from brown bears in Sweden and analysed from their dietary components. These samples came from 65 bears, of which 57 were adults and 8 were subadults. There were 49 females and 16 males. This study has shown a strong annual correlation between temperatures and the feeding behaviour of brown bears in Sweden. There was a significant annual variation in the diet of the bears, as well as the proportion of the components. Of the three berry species analysed, bilberry (*Vaccinium myrtillus*), was found declining in favour of lingonberry (*Vaccinium vitis-idaea*), and crowberry (*Empetrum hermaphroditum*).

Males eat significantly less bilberries than females and there are significant differences in the amount of bilberries that the bears eat per year. The quantity of bilberries decreased over time. The more bilberries consumed by the bears during a year, the less lingonberries and crowberries are consumed and vice versa.

Between 2015 and 2019, there are clear annual dietary variations. In 2015, bilberry made up 66.83%, lingonberry made up 1.96% and crowberry made up 0.89% of the diet of the bears. In 2016, the berry contents of bilberry, lingonberry, and crowberry were 59.01%, 1.21%, and 2.03% respectively. In 2017, bilberry was 24.49%, lingonberry was 7.79%, and crowberry was 13.31%. In 2018, bilberry rose to 36.64%, lingonberry rose to 10.57%, and crowberry rose to 25.05%. Lastly, in 2019, bilberry dropped to 5.56%, lingonberry rose to 27.78%, and crowberry was not present at all.

This data was compared to climatic variations in the area and the results were that there is a clear indication of an increased annual temperature with a steady incline from 2015 to 2019. The food items consumed by the bears seem resilient to colder temperatures, as there was little to no change in the feeding behaviour during 2015-2016. On the contrary, as temperatures rise from 2016 and onwards, changes happen in the feeding behaviours. Figure 6 shows a drastic temperature increase in 2019. This is mirrored by the results

shown in figure 7. In 2019, 0.01% insects were found in the bear scat. Oats decreased from 12.75% in 2018 to 5.54% in 2019.

In essence, all abovementioned figures are indicative of a relationship between climatic variation and the feeding behaviour of the brown bears. When climate changes, so does the feeding behaviour of brown bears.

Despite being able to be flexible in their dietary requirements and resilience towards changes in their surroundings and availability of resources, a changing climate and anthropogenic impact may affect the feeding behaviour of brown bears. These factors must be monitored in ordered to properly implement conservational and management efforts. As a keystone and umbrella species, any negative affect on the bear populations may drastically affect the entire ecosystem. Therefore, long term dietary studies can help to evaluate to what extent climatic change affects the feeding behaviour of the brown bear.

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Ch.1 Introduction

Research shows that humanity is facing two urgent and interlinked environmental challenges: biodiversity loss and climatic change (Shin et al., 2022). Climatic change refers to long-term changes in weather and temperature, brought on by human activities. This results in global temperature increases and extreme, unpredictable weather (Shin et al., 2022). The main drivers of climatic change are pinpointed to be the emission of greenhouse gases and deforestation. The main consequences of this are marked by the intensity and frequency of natural disasters, decrease in crop productivity, rise in sea level, and biodiversity loss (Shivanna, 2022).

Biodiversity loss is one of the causes of climatic change. There are three variables in particular that increase biodiversity loss: variations in precipitation, temperature, and the number of natural disaster occurrences (Habibullah et al., 2022). Economic development is also an attributing factor, as human expansion is an ever-growing threat on ecosystems (Adler et al., 2009). Climatic change can directly affect species by altering their physical environment. It can also affect species by indirectly altering interspecific interactions, such as competition and predation (Adler et al., 2009).

Climatic change is also causing changes across ecosystems. Perhaps most prominent and noticeable at the moment are the warming impacts on the earth and its species. Changes in plant diversity are more equivocal as the tundra warms than the consistent decline in the diversity of plants in drying landscapes (Chapin & Diaz, 2020). Analogous to the dryer landscapes, alpine and arctic ecosystems have a lower diversity rate than those in mesic environments. This suggests that these environments might gain diversity as climate warms. This could increase competition of species in these areas, causing non-native species to take over (Forzieri et al., 2022). As such, forest ecosystems depend on their capacity to recover and withstand anthropogenic and natural perturbations (Forzieri et al., 2022). Studies have shown that mitigating climatic change will be beneficial to insect biodiversity, as natural habitats would be preserved and the intensity of agriculture would be reduced (Outhwaite et al., 2022).

The impacts of climatic change are vast. Dramatic ecological responses to extreme events have been observed across ecosystems-, individual-, and population scales (Maxwell et al., 2018). For instance, cyclones can alter the onset of sexual maturity in turtles *(Chelonioidea)* (Dodd & Dreslik, 2008), prolonged droughts have ensured the population collapse in koalas *(Phascolarctos cinereus*) in parts of Australia (Seabrook et al., 2011), flooding has reduced the richness of plant species (Miller et al., 2010), and heat waves have altered the structure of marine ecosystems (Maxwell et al., 2018; Wernberg et al., 2013). Ecological responses are more pronounced when climatic change causes several extreme events to co-occur (Maxwell et al., 2018).

The study of cyclic and seasonal natural phenomena in relation to climate change is an important indicator of plant survival. Climate change can affect plant phenology in numerous ways. Plant phenology depends on certain set temperatures at certain times throughout the life cycle for optimum growth (Piao et al., 2019). Plant phenology is strongly controlled by the temperatures and climate around and has therefore consistently become one of the most reliable bioindicators of climatic change (Gordo & Sanz, 2010). As such, the current rapid climatic changes are challenging plant responses and causing consequences for the ecosystems. There are distinct trends of advanced leaf unfolding and delayed leaf colouring due to climatic change and warming trends(Piao et al., 2019). Furthermore, the changes in plant phenology have implications for the carbon cycles within an ecosystem, as well as the ecosystem feedbacks to climate (Piao et al., 2019). It is estimated that the differences in temporal responses of plant phenology to climatic changes are due to differences in sensitivity to climate among species and events (Gordo & Sanz, 2010).

Climate change could affect the feeding patterns of species (Burek et al., 2008). The overall health of an individual of any given species is defined by its complex interactions of body condition, immune status, pathogens, pathogenicity, and toxicant exposure. All of these factors are interacting with various environmental conditions at all times. Therefore, any change to these factors due to climatic change is bound to have an impact on the individual. As such, climatic change can be divided into direct and indirect effects. Direct effects include changes to the surroundings of the individual, such as habitat loss, water elevations, temperature changes, and increased occurrence of severe weather. Indirect effects include effects on body conditions due to shifts in prey base and the food web. Additionally, there could be alterations in pathogen transmission, changes in toxicant exposures, and increased pollution and chemical exposure due to increased human presence (Burek et al., 2008).

Climatic change can be especially problematic for hibernating species, such as bears (*Ursidae).* The hibernation period of brown bears in Scandinavia and North America stretches from around October/November to April/May, followed by the mating season in June and a breeding period in January. Brown bears are reliant on the accumulation of adipose tissues in summer and fall (hyperphagia) to survive hibernation. Brown bears are omnivores and spend approximately 2/3 of their days foraging (Leimer, 2021). It is estimated that brown bear populations may decline drastically as their food sources react to climate change (Penteriani et al., 2019). Several plant species are among the bear’s main food source during hyperphagia, such as bilberry *(Vaccinium myrtillus)*, crowberries *(Empetrum nigrum),* and lingonberries *(V. vitis idaea)* (Stenset et al., 2016). During a possible future climate warming, the availability of these plants may be altered and thus reducing the bear’s resources greatly (Penteriani et al., 2019). Additional negative effects of a loss of plants due to climate change might include a) a more carnivorous diet, increasing conflict with cattle farms, b) increased competition and intraspecific competition, c) limited fat storage, d) larger displacements between seasons (Penteriani et al., 2019).

A current example of negative effects of climate change is found in and around Yellowstone National Park (GrizzlyTimes, 2023). The bears in these lands confine their movements during late summer and early autumn to alpine areas. This is because one critical food source exists here: seeds of the Whitebark Pine *(Pinus albicaulis)*. Bears rely on this during hyperphagia. However, Whitebark Pine is threatened by the more frequent droughts and rising temperatures that are caused by global warming (Keeler, 2023). Mountain pine beetles *(Dendroctonus ponderosae)* are experiencing an unprecedented increase due to a warmer climate. These beetles are attacking the trees even in higher elevations. As a result, 51% of Whitebark pine has suffered high mortality, while another 31% is experiencing significant mortality (GrizzlyTimes, 2023). This has potential long-term negative effects on the bears residing in these areas and their hyperphagia.

As a consequence of climate change, this decrease will have negative effects on the bears, as it is documented that the seeds has a positive effect on female reproductive success, in which the consuming of these seeds provides densely compact nutrition that leads to larger litters and an increased reproduction likelihood following good pine seed crops (Mattson, 2000). Whitebark pine has also been proven to reduce human-caused mortality, as the seeds force the bears into remote high-elevation areas away from people (Mattson, 1997).

Warmer temperatures brough on by climate change can lead to bears leaving their dens too soon, putting them at risk of emerging from their dens before plants and berries have had a chance to revive after the winter. (Beck, 2022). Energy budgets, reduced cub survival, cub fitness, and increased human-bear conflict are all possible results of climate-induced changes in the phenology of bear hibernation. Additionally, climate change is responsible for changing the phenology of the so-called spring green-up and the onset of winter. This disrupts the seasonal behaviour of species and adds strain on threatened populations (Pigeon et al., 2016).

The brown bear is considered a keystone and umbrella species due to the necessity of their presence for a healthy functioning ecosystem(The University of British Columbia, 2023). As such, the brown bear is a species that is noticeable important as a food chain regulator, with strong top-down effects. If the species were to be forced out of habitat due to climate change, their absence could result in trophic cascades. An example of this has already occurred in Yellowstone National Park, in which the wolves were not present to regulate the native ungulate species, such as moose and deer. Without regulation, the species experienced an uncontrolled boom that decimated local vegetation, rapidly decreased biodiversity and food sources (The University of British Columbia, 2023). As omnivores, the loss of bears would therefore spread out to all corners of the ecosystem, both in the terrestrial and aquatic realms.

Sweden boasts a number of big carnivores, such as brown bear *(Ursus arctos)*, wolverine *(Gulo gulo)*, Eurasian wolf *(Canis lupus lupus)*, Eurasian lynx *(Lynx lynx)* *(Natural Resources Institute Finland, 2023)*. The brown bear population in Sweden is estimated to be around 2900 (Naturvårdsverket, 2017). These bears can be found in the Northern two thirds of Sweden, with Dalarna, Gävleborg, and Jämtland being the most densely populates areas (WildSweden, 2023). Brown bears have a lifespan of 20-30 years, in which the females can weigh up to 205 kg and the males 390 kg (International Association for Bear Research and Management, 2023).

Selective hunting and destruction of habitats has for long threatened to wipe the species out completely (Leimer, 2021). Despite conservational efforts that have largely protected the brown bears of Sweden since 1898, an increased human population has resulted in large-scale destructions of woodlands and forests, in favour of farmland and settlements, thus destroying bear habitat (Leimer, 2021). The encroachment of humans on both a physical level and a climate change level is a challenge for those entirely dependent on the natural world.

I focused on the following research questions:

1)Is there a change (increase or decrease) in the proportion of bilberries, lingonberries, and crowberries consumed by bears in autumn (hyperphagia) during the study period?

2)Is there a difference between the sexes in proportion of bilberries, lingonberries, and crowberries consumed by bears in autumn (hyperphagia) during the study period?

3)Do annual climatic variations affect the dietary variations during the study period?

Ch.2 Materials and methods

Study area

The data was collected in Sweden, in the counties of Gävleborg and Dalarna, which lie at 61°5′ N, 15°05′ E. The exact study area is shown in Figure 1. The bear population density is approximately 30 bears per 1000km² (Zedrosser et al., 2006). Comparably, there are 4-7 humans per km² inhabiting the study area (Martin et al., 2010; Ordiz et al., 2013).

The forests are intensively managed. This process has produced two species of coniferous forest which are especially dominating, namely Norway spruce *(Picea abies)* and Scots pine (*Pinus sylvestris)* (Martin et al., 2010; Swenson et al., 1999). Of the forest in these areas, it is estimated that approximately 80% is managed, with roughly 40% being younger than 35 years (Linder & Ostlund, 1998; Swenson et al., 1999). The understory vegetation is dominated by berry species, such as lingonberries, crowberries, and bilberries (Elfstrøm et al., 2014; Swenson et al., 1999). The average precipitation is approximately 600-1000 mm annually (Lundqvist, 2002), and the length of the vegetation period is approximately 140 days (Hertel, Zedrosser, et al., 2018). The mean temperatures in January and July are 7.8C and 15.8C respectively (Moen, 1998). Snow cover lasts from late October until early May.

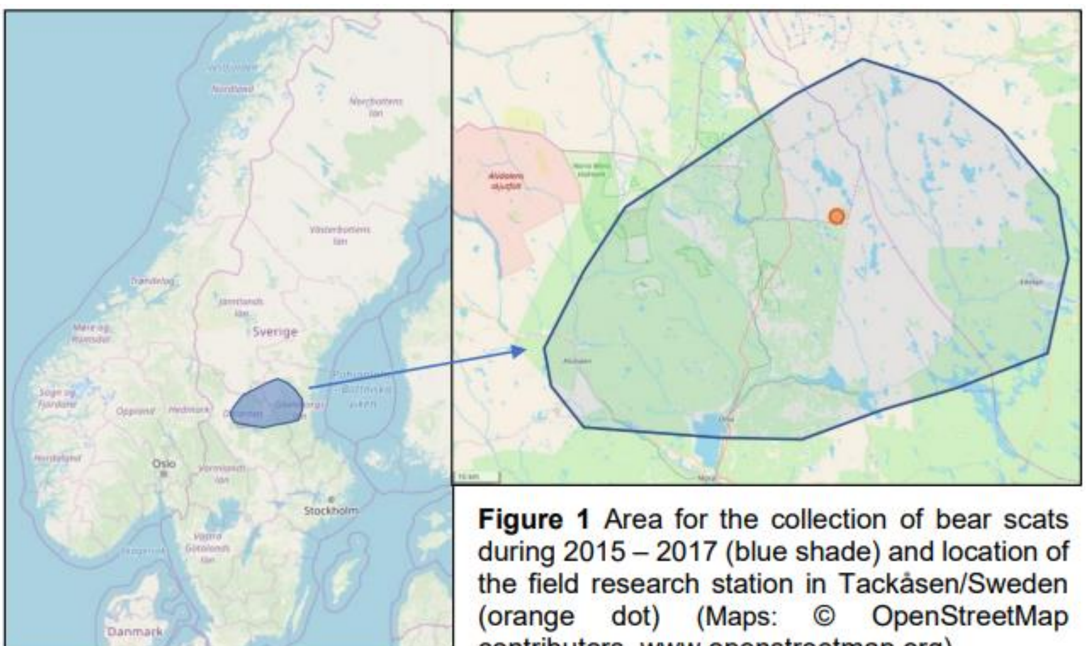

Figure 1 Area for the collection of bear scats during 2015 – 2017 (blue shade) and location of the field research station in Tackåsen/Sweden (orange dot) (Maps: © OpenStreetMap contributors, www.openstreetmap.org)

Figure 1- (Franke, 2019b)

Scat sample collection

The Scandinavian Brown Bear Project radio tracks bears with GPS-GSM collars (Scandinavian Brown Bear Project, 2023). These collars have a relocation schedule of 30 minutes. Capture and handling follows the procedure outlines by Arnemo and Evans (Arnemo & Evans, 2017). This allowed the location of "resting sites" to be visible, which is where the bear spent at least 1.5 hours or more, with three location tracks within a 30 meter radius (Ordiz et al., 2011; Rauset et al., 2012). The locations of these sites was uploaded in a hand-held GPS unit and visited in the field (Franke, 2019a).

Scats were collected from every independent radio-collared individual, (i. e. bears not part of a family group) on a weekly basis in 2015, biweekly from 2016-2021. The samples were usually collected during May and lasted until late September. In 2019, scat was collected mainly between May and early September. During this period, it is assumed that this scat collection was ended earlier due to snow cover and road conditions. In this thesis, only the scats collected during hyperphagia (July-September) were used.

To avoid the scat collection of unknown individuals, scats were only collected if only one bed was present. In this case, the 'bed' refers to a bedding sight in which the bear has chosen an area to rest. This area is defined by finding evidence in vegetation, such as flattened out areas and/or damaged plant material, and the bear's hair was found inside the bed (Ordiz et al., 2011). The criteria for scat collection was that the only scat to be used for sampling was the scat found within a 5 meter radius around the active bed-site (Franke, 2019a). The collected scats were stored in labelled in plastic bags and frozen at -20C until further analysis.

Dietary analysis

The samples analysed as part of this thesis were collected from 2019-2021. Samples collected in earlier years had previously been analysed by Klamarova and Franke (Franke, 2019a; Klamarova, 2019). For this thesis, I analysed samples collected from 2015-2019. The analysis of the abovementioned scats was conducted in a laboratory at USN Bø. The dietary analysis was conducted by following the procedures described in the lab manual of appendix 1 by (Dahle et al., 1998; Franke, 2019a; Stenset et al., 2016) (See Appendix 1 for the lab manual). The samples were first taken from the freezer and defrosted at room temperature. Once defrosted, the sample bag was weighed in its entirety in grams and then the volume of the scat was determined by water displacement (Dahle et al., 1998). However, the volume measurements will not feature in the final calculations, as volume was found to have no correlation with the dominating item of food in the scat (Stenset et al., 2016).

An important factor before the physical examination of the scat was to first homogenize the sample. This was done to ensure an evenly mixed sample. The bag was then opened, and three scoops of scat were collected with a 5 ml spoon and divided onto three sieves with a 0.8mm mesh. Each sample was rinsed under water until only solid items remained (Figure 2).

Figure 2a) Washed bear scat subsample on tray (unsorted); **b)** sorting of scat items on tray; **c)** insects derived from bear scats (I: larvae; II: *Formica sp.* ; III: *Camponotus sp.*); **d)** berries derived from bear scats (IV: bilberry; V: crowberry; VI: lingonberry; VII: raspberry). (Pictures in 2c and d by J. Rietz).

Figure 2-(Franke, 2019b)

The subsamples were then spread on a plastic disc and sorted into groups and their proportion visually estimated (Dahle et al., 1998; Franke, 2019a). This process is deemed appropriate, as the visual estimates correspond well with exact volumes according to (Mattson et al., 1999). Furthermore, the samples were divided based on taxonomic groups. These groups were bilberry, lingonberry, crowberry, ants/insects (Formica, Camponotus, unidentifiable ants, egg/larvae, other), vertebrates (bones, hair moose, hair other), vegetative material (graminoids, oats, other), and other (miscellaneous).

A microscope was also used to determined miniscule or uncertain items. Items such as pebbles, bark, leaves, and tree needles were not included as dietary items (Franke, 2019a). For the purpose of this thesis, I focused on samples collected during hyperphagia season, which lasts from July to September.

<u>Statistical analysis</u>

I used a generalized linear mixed model (Zuur et al., 2009) with a binomial distribution to analyse annual variations in the proportions of bilberry, lingonberry, and crowberry consumed. As bilberries are the major dietary item of brown bears during hyperphagia in Scandinavia (Dahle et al., 1998; Franke, 2019a; Stenset et al., 2016), I used the proportion of bilberry during hyperphagia as the dependent variable, and as the explanatory variables I used the proportion of lingonberry, the proportion of crowberry, sex (as a factor, 0= female, 1= male), age (as factor 0= subadult (ages 1-3), 1=adult (4 years and older)), and year. I used the bear's individual ID as a random factor (Zuur et al., 2009). For several reasons I chose year rather than temperature or precipitation to reflect annual variations in climate; year has been found to sufficiently represent annual variation in food and climatic conditions in several studies and species (Hennessey et al., 1992; Saether, 1985; Stenset et al., 2016).

In addition, it is difficult to pinpoint which climatic conditions affect berry production at a local scale due to small-scale climatic variation and small-scale variations in growth conditions. Also, a model including mean temperatures and mean precipitation during the months of spring (April-June) as well as a model including mean temperatures and mean precipitation during hyperphagia season (July-September) did not yield any statistically significant results. This was likely due to the inability to sufficiently represent local variations in climatic conditions.

Ch.3 Results

In total, 352 samples were collected and analysed during hyperphagia season from 2015-2019. These samples came from 65 bears, of which 57 were adults and 8 were subadults. There were 49 females and 16 males. The proportions of the main food items (Figure 3) as well as berries (Figure 4) varied greatly during the study period. I found no significant difference between years in the proportions of berries (all berries combined) compared to the proportion of other food items (all food items combined) during the study period (X^2= 20, df=16, p=0.220).

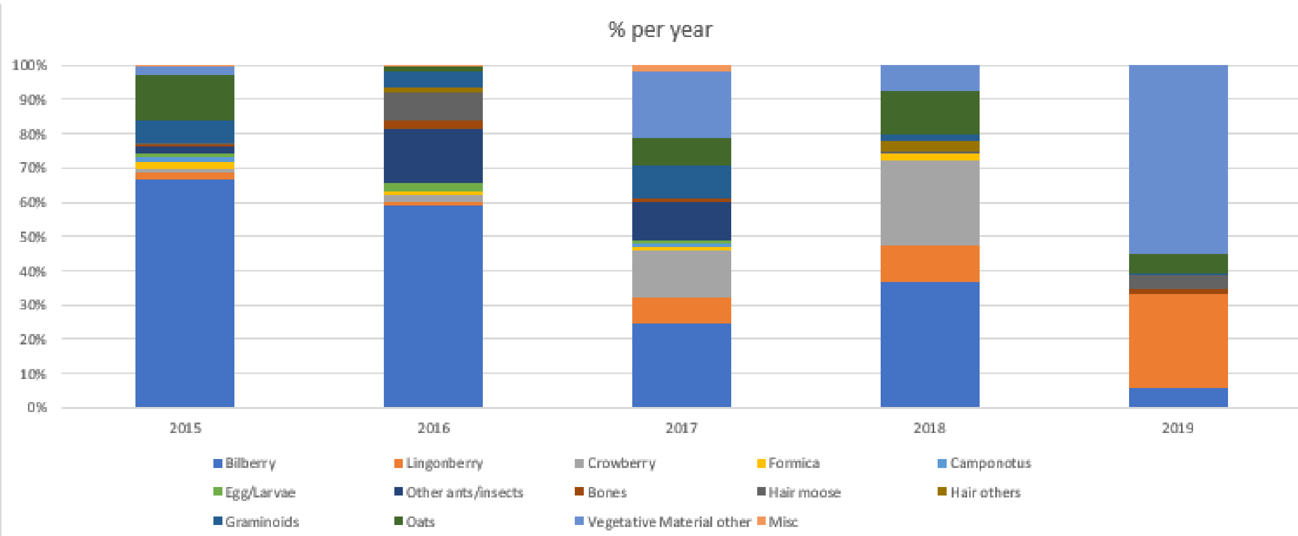

Figure 3- Proportions of food items consumed by brown bears during hyperphagia season (July-September) in Sweden from 2015-2019

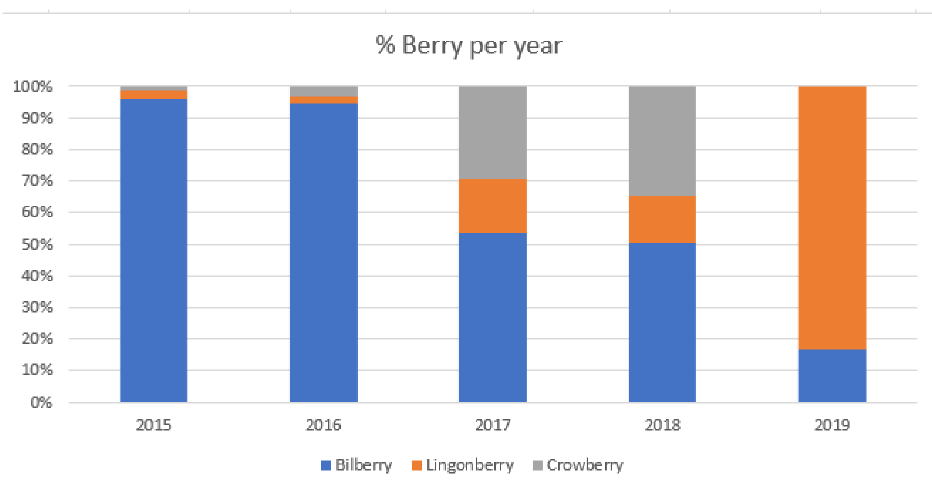

Figure 4- Proportion of berry species consumed by brown bears during hyperphagia season (July-September) in Sweden from 2015-2019.

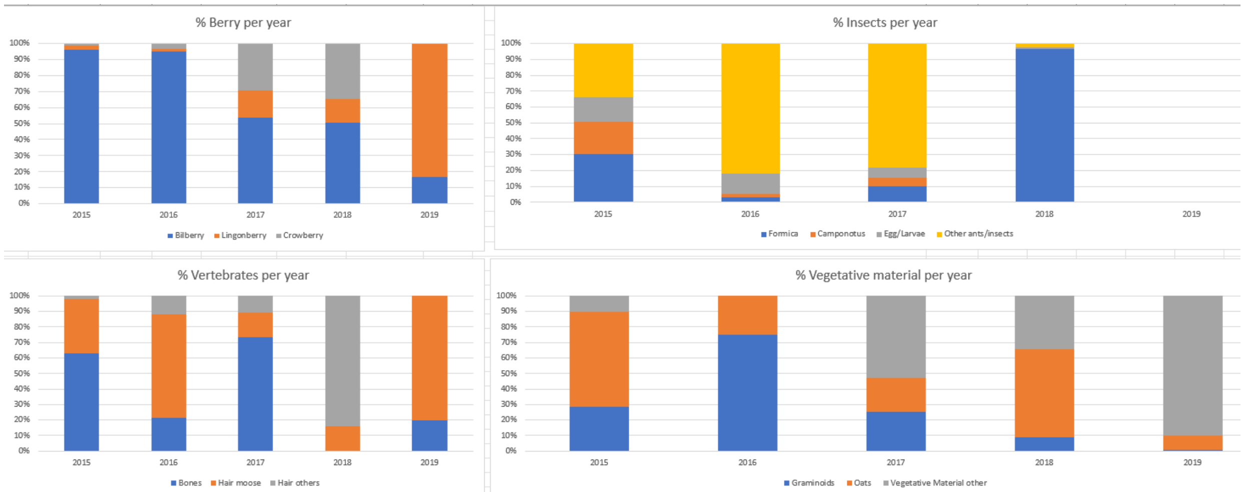

Figure 5- Proportion of all food items consumed by brown bears during the hyperphagia season (July-September) in Sweden from 2015-2019.

A generalized linear mixed model showed that the annual proportion of bilberry consumed was significantly lower in males compared to females. Additionally, it showed that it decreased significantly over time (i.e. was negatively correlated with year), and decreased significantly with increasing proportions of lingon- as well as crowberries (Table 1).

Table 1- Results of a linear mixed model estimating annual variations of the proportion of bilberry eaten by brown bears during the hyperphagia season (July-September) in Sweden, 2015-2019.

Variables	Estimate	SE	df	t	p
Sex					
female	0	0	0	0	
male	-0.942	0.340	286	-2.774	0.006
Year	-0.468	0.077	286	-6.047	<0.001
Lingonberry	-2.366	0.797	286	-2.970	0.003
Crowberry	-2.287	0.511	286	-4.478	<0.001

Because I did not directly control for climatic variables in the mixed effects model but rather chose the variable year, below I present an overview of the general trend of mean annual temperatures in Sweden during 2000-2020 (Figure 6). When looking at the period between 2015-2019, there is a clear indication of an increased annual temperature with a steady incline.

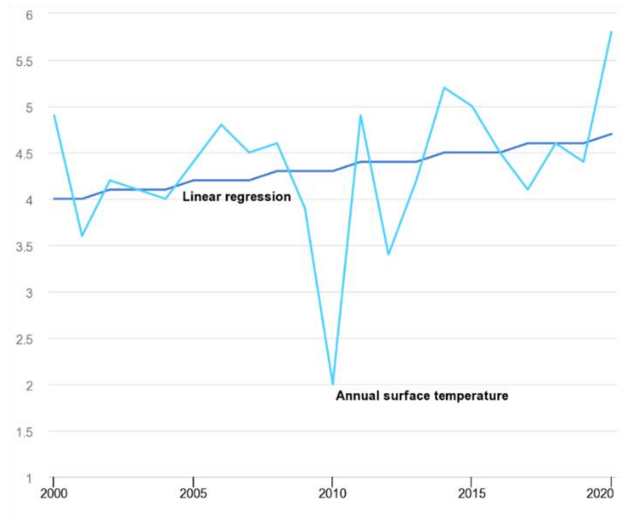

Figure 6- Trend in mean annual temperatures in Sweden 2000-2020 (IEA Statistics, 2023)

Ch.4 Discussion

For this study, 352 samples were collected during hyperphagia season and analysed. Berries are an important food item during hyperphagia. However, their importance can vary between years. The proportion of bilberries eaten decreased with increasing amounts of lingon- and crowberries. Females generally consumed more bilberries than males. I found a strong negative correlation between climatic variations (represented by the variable year), and the proportion of bilberry consumed annually; bears consumed lower proportions of bilberries over time during the study period.

Bilberry was the berry species most frequently consumed by bears during hyperphagia. This result is similar to results found previously by (Franke, 2019a; Stenset et al., 2016). Bears maximize their energy intake by foraging on plants that provide high bite rates, as well as larger bite sizes, due to the clustered growth pattern (Welch et al., 1997). Bilberries grow less clumped and have larger leaves, compared to lingonberries and crowberries (Welch et al., 1997).

Bears select bilberries for their higher carbohydrate content and better macronutrient composition (Hertel et al., 2016). The results further indicate that in years with low bilberry availability, bears forage more on lingonberries, as well as crowberries. It appears that especially crowberries are mainly eaten in years with low availability of bilberries, and/or lingonberries. Similar results have been found in (Franke, 2019a; Stenset et al., 2016) as well.

Other food items, such as vegetative materials and vertebrate items seem to replace berries in years with low berry availability. The most amount of vegetation was consumed in 2019, when berry consumption was the lowest. These items were all vegetative materials consumed, apart from oats and graminoids. Similar studies claim that during low berry crop production years, bears will look for food sources elsewhere. Depending on their proximity to humans, they will choose food sources that yield a similar energy intake, such as various vegetations, rumen contents of a carcass and honey (Bojarska & Selva, 2012; Rogers, 1976).

Interestingly, ants and insects showed varying levels throughout the years. Previous studies by (Johansen, 1997), suggested that the annual intake of ants and insects in the study was around 20%. In this study, however, ants and insects only made up 4.32%, 19.07%, 14.41%, 1.68%, and 0.01% in 2015, 2016, 2017, 2018, and 2019 respectively. According to (Swenson et al., 1999), bears consume more ants, especially carpenter ants, when the production of berries is low and crops are more. In this study, the year with the highest insects consumed was 2016. During the same year, berry intake decreased slightly. However, this is not comparable as the berry intake for 2017 to 2019 decreases further while not matched by insect intake. As such, the consumption of ants and insects in this study did not change accordingly to the availability of berries in autumn.

The consumption of vertebrate items, such as moose, remained stable throughout the years. Moose and the other food items of this group are valuable sources of protein for the rabid mass gain in bears. This is especially important in spring (Lopez-Alfaro et al., 2013). However, the foraging and consumption of vertebrates is highly energy draining, so (Rodes & Robbins, 2000) claim that foraging on insects is a more energy efficient feeding behaviour for brown bears. Bears are particularly prone to prey on moose calves, rather than adult moose (Rauset et al., 2012). Studies have claimed that the consumption of a mixed diet could affect seedling dispersion and propagation (Rodes & Robbins, 2000). Rodes also suggested that the reason for this is that the bears consume mixed diets in order to avoid the high maintenance costs of the metabolism. This would result in scat containing fewer seeds and rarer dispersion. An important factor that should be considered is the climatic variation and changes that have occurred throughout the years. Bear populations that live in areas with colder temperatures and deeper snow cover consumed more vertebrates. This led to a lowering in productivity. These bears would also consume less berries and fewer insects (Bojarska & Selva, 2012). As such, this study found a steady increase in the moose hairs found and a steady decrease in the number of moose bones found. This does not appear to have had an impact on the overall consumption of vertebrate food items.

The results show that females eat bilberries more frequently than the males. Studies have shown that the consumption of bilberries is crucial to female bears before hibernation (Beck, 2022; Lopez-Alfaro et al., 2013; Pigeon et al., 2016). This because autumn and spring weight of the yearlings increases with bilberry abundance, while a lower abundance in the berries resulted in lower reproductive success and females that were classed as lightweight (Hertel, Bischof, et al., 2018). Also, females need at least 18% body fat content to be able to implant embryos in November and successfully reproduce (Lopez-Alfaro et al., 2013). Environmental conditions have been shown to significantly affect the life history in brown bears. This is visible in compensatory growth (Zedrosser et al., 2006) and the bear's body condition as a subadult in relation to reproductive success (Zedrosser et al., 2013). Nevertheless, studies show that bears have an ability to compensate with other berry species if there is a lack of bilberries (Stenset et al., 2016).

The proportion of bilberries consumed by bears during hyperphagia decreased over time, likely due to climatic variations. Bilberries thrive best with late frost, mild winters, and higher precipitation during the summer months (Nestby et al., 2011). These events are prognosed to occur more frequently during future years, which may increase the importance of the availability of alternative food items, such as other berry species or other vegetation (Bojarska & Selva, 2012; Penteriani et al., 2019).

Despite this, studies claim that bilberry can potentially sustain climatic changes and has the ability to recover from sporadic frost events, whilst milder winters and longer growing periods could potentially be positive for bilberry production (Hertel, Bischof, et al., 2018). According to (Hertel et al., 2016), lingonberries occur up to three times more frequently during early September, which is the end of the field sampling season. The bear scat collection was ended during early September each year due to logistical reasons, which may have resulted in an underestimate of lingonberry during hyperphagia season.

Studies portray that bears can vary between berry species, based on the berries' availability and abundance. Crowberry is named as the replacement berry by studies in which bilberry is not available (Hertel et al., 2016; Stenset et al., 2016). Based on this, the bears in this research should have compensated the declining amount of bilberry with consuming more crowberry. According to my data, crowberry was indeed more prevalent from the years 2016-2018. However, during 2019, lingonberry was consumed most. Interestingly, this has not been found to be the case by previous studies, which claim that bears do not turn to lingonberries during years of low bilberry abundance (Hertel et al., 2016; Stenset et al., 2016). Hence my study cannot confirm the reason why this occurred, only that it did.

Various studies highlight the importance that the role of berries play for bears. The fluctuating berry abundances have been thought not to affect bear foraging behaviour, according to (Hertel, Bischof, et al., 2018). However, other studies have shown that these abundances and the availability to these berries can be the reason for bear densities being low or high (Mattson et al., 1990; McLellan & Hovey, 2011). Additionally, (Stenset et al., 2016) suggests that berry availability may reduce the carrying capacity of the forests for the brown bears in Sweden.

Ch.5 Conclusion

In conclusion, climatic variations affect the diet of brown bears in Sweden, especially the amount and proportions of berries eaten in a given year. Climate change is affecting species on a global level. Nordic areas are especially sensitive, with temperatures in Scandinavia rising faster than in many other countries on earth (Walther et al., 2002).

Despite the dietary flexibility of brown bears and their resilience towards changes in their surroundings and availability of resources (Bojarska & Selva, 2012), a changing climate and anthropogenic impact may affect the feeding behaviour of brown bears in the future. These factors must be monitored in ordered to properly implement conservational and management efforts. As an umbrella species, any negative affect on the bear populations may drastically affect the entire ecosystem. Therefore, long term dietary studies can help to evaluate to what extent climatic change affects the feeding behaviour of the brown bear.

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Appendices

Appendix 1: Laboratory pictures

Appendix 2: Lab manual

<u>Lab Protocol: Scat analysis</u>

Scope

Scat analysis is a really simple, cheap and effective way of getting an overview about the bears diet. The method used here is based on the published work of Hamer and Herrero (1987), Dahle et al. (1998) and Stenset et al. (2016). Summarized, the scat is divided in a series of subsamples which are analyzed separately, and the mean value then is used for further calculations and statistical analyses. Scat collection procedure is described in a different protocol.

Safety

Bear scats are feces: they possibly transmit disease and parasites. ABSOLUTELY NO BEAR SCATS inside the field station. Analysis and storage take place in the "freezer garage". Don't wash or analyze scats without gloves. When you're done, turn the gloves inside out while taking them off and dispose.

Sample Preparation

After scat collection, all scats are labelled and stored in the freezer. A couple of hours before you want to start analysis, take the scats out of the freezer and put them outside for thawing. Check the labels and the corresponding field collection protocol to see if something is odd with this scat or if it even is meant for analysis.

Materials needed

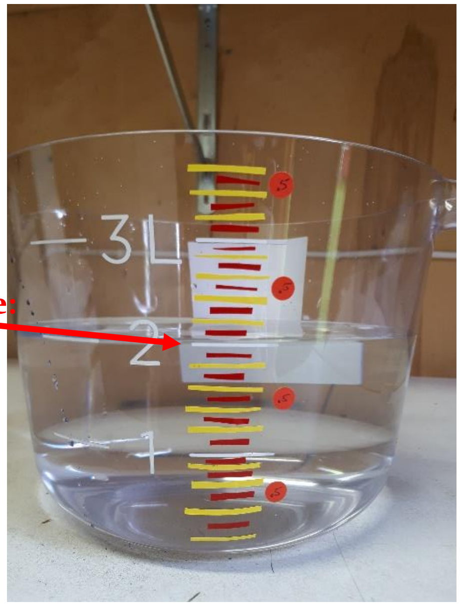
- Tweezers
- Gloves
- Waste bags
- Water hose
- 5 strainers with 0.8mm grid
- 50ml measuring cup/spoon
- scale
- 1 l and 3 to 5 l measuring jug with 100ml intervals
- Sample trays/ lids
- Paper towels
- Pen and Lab Protocols
- Some music or a conversation partner is recommended

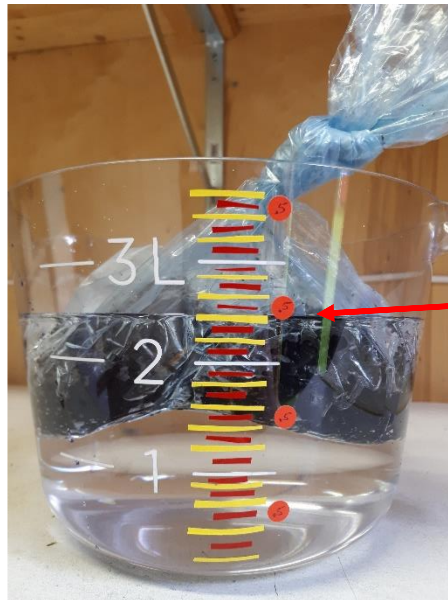
Protocol

1. Before starting, fill in the header of the lab protocol (Sample ID = Protocol ID) and check the field collection protocol.
2. Remove the inner plastic bag from the ZipLoc bag and weight the scat (in g).
3. Open the inner plastic bag and compress the scat and press as much air out as possible before tying it again. Take volume measurement by water displacement: Fill a defined amount of water in a measuring jug and submerge the scat with the inner plastic bag in the water. The scat needs to float freely in the water without touching the walls; if needed, use a thin object (for example, a twig) to fully submerge the scat. Note down the

difference between old and new “water level”, this is the approximate volume of the scat in ml. Attention: Accuracy should be in the 100ml scale; 3 to 5l measuring jugs are recommended for bigger scats and smaller measuring jugs for smaller scats, as the accuracy is better.

Before: 2l





After: 2.4l

Scat Volume: <u>400</u>

4. Thoroughly homogenize the scat, by “kneading” it with fingers while the scat is still in the inner/thin plastic bag.
5. Take 5x 50ml subsamples and put each one in a separate 0.8mm mesh sieve.

6. Rinse each subsample under water until only solid items remain in the strainer. Then empty the contents of each strainer on a separate analysis tray.

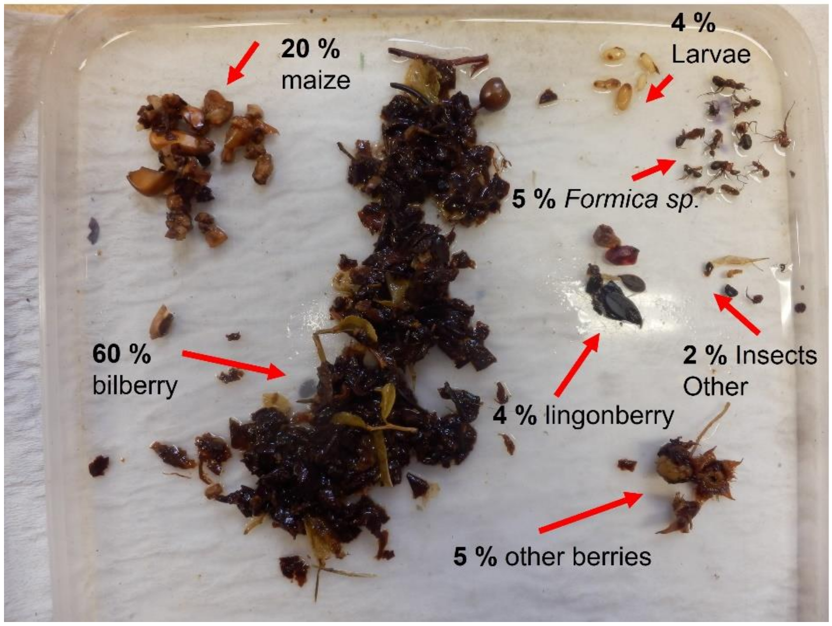
7. Sort the items on each tray by class.


Two examples for bear scat subsamples washed and sorted on a tray for food analysis.

8. Visually estimate the proportions of each food item for every subsample and note in the protocol.
9. Transfer all protocols to the Excel file!

Visual estimation of proportions

This part, of course, is a judgement by the observer and thus a potential bias that should be trained (it helps if 2 different persons estimate the contents of a tray in the beginning and then values should be compared). The total always is 100%. Here is an example:



Sorting and Identification of Food Items

The 3 most common berries and their leaves in bear scats

<u>Berries</u>

Sometimes digested berries are hard to identify. Check the scat for berry leaves to get a hint. Bilberry leaves for example are counted as bilberry! Berries also can be identified by the navel and seeds (the navel is very characteristic for bilberries, crowberries have very big seeds). If you have doubt: categorize them as 'Other vegetation' (just as other berries like cloudberries or raspberries) and note in the comments that it was digested berries that were hard to identify.

Nave

Bilberry

(www.greenandfreshmontreal.ca)

Lingonberr

(www.thedailymeal.com)

(Opiola Jerzy)

Attention: sometimes bog bilberry (*Odon*) can be found in bar scats. However, they are really hard to distinguish from bilberries. The berries are typically bluer and bigger than bilberries.

(www.healthbenefitstimes.com)

Attention: Color is not a good indicator! When different berries are eaten, e.g. bilberry and lingonberry, the whole berry mass is colored blueish.

<u>Material with no nutritional value/ side material</u>

Check the field protocol if it states that there was a lot of bymaterial collected along with the scat! Generally, bark, mosses, pebbles, pine needles, wood fragments and debris and dry leaves are sortet out and NOT CALCULATED in the visual estimation. They basically get treated as not there (but note in the comments if you observed for example a big amount of wood fragments).

<u>Graminoids and oats</u>

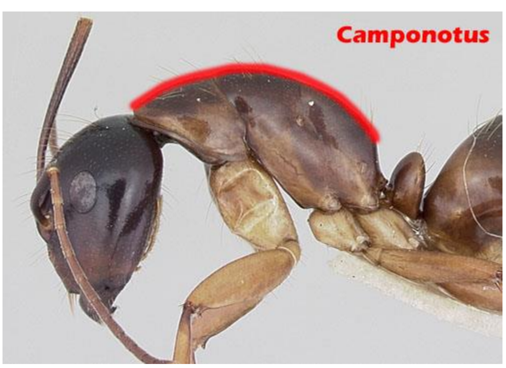
If there are graminoids together with oats, then this is counted as oats. Leaves with parallel veins are counted as graminoids.

Bones

Pay attention: sometimes small pieces of stones can be mistaken for bones. Slam them at a piece of metal if you are not sure (sound!) or try to break them with the scissors.

Ants/ Insects

Field ants and carpenter ants are easy to confuse; both are common, medium-large in size, with a single waist segment. As they are in the same subfamily, they have a similar appearance. The bump is used to determined if larger ants are *Camponotus* or *Formica*; use a stereoscope, if necessary!



A continuous profile indicates Camponotus. (Image by Antweb.org)

A profile with two distinct convexities indicates Formica. (Image by

This trick works only to separate *Formica* from *Camponotus*. Many similar *Formicinae* genera occur, but these are usually smaller than *Formica* & *Camponotus*, but be aware they exist.

Thus, smaller ants or ants where the category is not clear are categorized as “Other”. Ant heads (even though you are sure they “look like Camponotus because there is a lot of camponotus in the scat”) get also counted as other. Again, note in the comment field. Many larvae are having a party in the scat after it was disposed by the bear; those do not get counted as larvae; the category larvae only consists of ant larvae. Others get counted as ‘Other Insects’. Dung beetles also get treated as “not being there”, as they most likely came after the bears did its business.

Ant larvae that get counted as larvae (Image by Archibald Biological Station; Alex Wild)

Waste disposal

If there is scat left, refreeze it in is original bag and ZipLoc bag marked with ANALYZED; put it in a separate big black trashbag in the freezer, so it is clear that this scat was already analyzed. If you used all of that scat, note in the comment section. Also do that if the scat was not big enough for 5 subsamples and note how many subsamples you analyzed. The remains from analysis can be disposed in a trashbag, sealed good and disposed in the general waste bin.

Tips and Tricks

→ The comment field is gold: note everything that is odd or could be valuable information. E.g. Misc. items were mushrooms. Other vegetation consisted mainly of other unidentified berries etc. Also, if you realize that the scat was very dried out, as this might have an effect towards volume and weight measurement.

→ Especially with the berries it can be hard to identify them. To not skew the result and put them per default in the “Other vegetation” section, I recommend looking through the scat for berry seeds with your fingers BEFORE WASHING. If you only see bilberry seeds, but don’t find any crowberry, and the berries match accordingly, you can classify them as bilberries.

Lab Protocol

Protocol ID	Bear ID	Bear name	Date (DDMMYY)	Observer

Total scat	
Weight (g)	Volume (ml)

	SAMPLE 1		SAMPLE 2		SAMPLE 3	
Berries	Bilberry		Bilberry		Bilberry	
	Lingon		Lingon		Lingon	
	Crow		Crow		Crow	
Insects	Formica		Formica		Formica	
	Camponotus		Camponotus		Camponotus	
	Egg/larvae		Egg/larvae		Egg/larvae	
	Other		Other		Other	
Mammals	Bones		Bones		Bones	
	Hair moose		Hair moose		Hair moose	
	Hair other		Hair other		Hair other	
Vegetation	Graminoids		Graminoids		Graminoids	
	Oats		Oats		Oats	
	Other		Other		Other	
Other	Miscelenious		Miscelenious		Miscelenious	
	TOTAL		TOTAL		TOTAL	

	SAMPLE 4		SAMPLE 5	
Berries	Bilberry		Bilberry	
	Lingon		Lingon	
	Crow		Crow	
Insects	Formica		Formica	
	Camponotus		Camponotus	
	Egg/larvae		Egg/larvae	
	Other		Other	
Mammals	Bones		Bones	
	Hair moose		Hair moose	
	Hair other		Hair other	
Vegetation	Graminoids		Graminoids	
	Oats		Oats	
	Other		Other	
Other	Miscelenious		Miscelenious	
	TOTAL		TOTAL	

Comments

Protocol ID: ID in field protocol

Date: Date of analysis

Observer: Person doing the lab analysis

Volume: ml of water displacement

Bilberry: Bilberry and Bilberry leaves

Lingon: Lingonberry and Lingonberry leaves

Crow: Crowberry and Crowberry leaves

Formica: big ants with the divided carpax

Camponotus: big ants with the even carpax

Egg/ larvae: only of ants!

Ins. Other: insect parts, ant heads, small ants, wings. Other larvae.

Bones: all bones.

Hair moose: hair of adult or calf

Hair other: Other hair you can’t identify; bear, hare, deer etc.

Graminoids: leaves with parallel veins, grasses