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Arthropod biomass and abundances in mature clear-cut versus mature near-natural boreal forests in southeastern Norway

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Master of Science in Natural Resource Management

Preface

This is the final product of my Master of Science in Natural Resource Management at the Norwegian University of Life Sciences (NMBU). I would like to thank my supervisors Anne Sverdrup-Thygeson and Tone Birkemoe for their invaluable support and guidance throughout the whole year. Warm thanks to Tone Granerud for use of the entomology lab and advice with species identification. I would also like to thank UNIFOR (NMBU research fund) for providing necessary research funding which made the field work possible. Grateful thanks to Statskog for use of old timber cabin in the remote forest at Gravberget, waking up there and picking ripe cloudberries to add in our breakfast muesli was a highlight of the field work. Last but not least, I thank my student collaborator Geneva Lish for being the best field and lab partner I could have wished for and well as an excellent discussion partner in the final phase.

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Abstract

The loss of biodiversity in forest ecosystems has led to a discussion on conservation-oriented forest management, particularly in intensively managed boreal forests of the northern hemisphere. Clear-cutting is the most common forest management practice in Norway today. Clear-cutting differs from other less intensive forest management practices like selective logging which result in a more natural looking and heterogeneous forest (near-natural forests). Many of these clear-cut forests are now reaching maturity making it possible to determine the long-term effects of clear-cutting. Previous studies on effects of clear-cutting have been done, but there is a lack of studies revealing the effects on all arthropods. To assess difference between the two forest management practices on all arthropods, I sampled arthropods in five pairwise plots in southeastern Norway, each pair consisting of one mature near-natural site and one mature clear-cut site. Forest stand variables related to forest management, such as deadwood, canopy openness and temperature were also registered. I used three different window trap types as well as malaise traps, and their efficiency at beetle capture was also tested.

I found that clear-cutting had a long-term impact on both arthropod biomass and abundance, as the difference is still clear 70 years after the clear-cutting took place. Overall, the mature clear-cut forests had lower total arthropod biomass and abundances compared to mature near-natural forests. The response of different arthropod orders to forest management practice varied greatly between taxonomic orders. Although most orders showed higher abundance and biomass in near-natural forest, some orders showed the opposite pattern. Previously clear-cut forests are more homogeneous, contain less deadwood and likely attract more generalist species. My results suggest that there might be community differences between the forest management types amongst several arthropod orders, most notably Diptera, Lepidoptera and Collembola. With this study I show the differences between selective logging and clear-cutting as forest management practices on arthropods and the importance of preserving near-natural forests. In addition, my systematic comparison of trap types, shows that traps vary greatly in beetle capture rates and that single pane window traps such as IBL-2 are more efficient than cross-pane traps.

Contents

1 Introduction

Current data suggests a declining trend in insect diversity and abundance worldwide (Conrad et al., 2006; Hallmann et al., 2017; Sánchez-Bayo & Wyckhuys, 2019; Wagner, 2020). Insects make up a large part of arthropods, but terrestrial arthropods also include other important orders such as spiders and springtails. Arthropods provide key ecosystem functions such as pollination, herbivory, decomposition, nutrient cycling as well as being a major food source for many vertebrates. Arthropod biomass is important to studies of ecosystems because of the great abundance of arthropods, as well as their functional and taxonomic diversity (Noriega et al., 2018). There have been reports of reduced biomass and population declines among flying insects (Hallmann et al., 2017) and loss of diversity amongst a variety of arthropods and insect orders across Europe and North America (Brooks et al., 2012; Conrad et al., 2006; Potts et al., 2010; Sánchez-Bayo & Wyckhuys, 2019; Thomas et al., 2004). It appears that the rate of insect species declines are greater than those observed in birds or plants over the same time periods (Thomas et al., 2004) and changes in insect biomass could trigger wide-ranging cascading effects within the world's ecosystems (Sánchez-Bayo & Wyckhuys, 2019).

Most studies on insect or arthropod trends are limited to certain well know taxa (Karlsson et al., 2020). However, declines of specific groups of taxa do not necessarily reflect the general state of the local population. The total insect biomass would be a better measurement for the status of the population in its entirety, but few such studies have been conducted over a longer time periods (Hallmann et al., 2017). One such study from 2017, is a 27-year long population monitoring study, revealing a 76% decline in flying insect biomass across their study sites in protected areas of Germany (Hallmann et al., 2017). One limitation of the Hallmann study (2017) is that they only looked at the total biomass from each sample. Different taxonomic groups can respond differently and vary greatly in size and abundance. Changes in specific taxonomic orders can therefore make a big difference in total biomass especially if the group is comprised of relatively large and heavy individuals (Sánchez-Bayo & Wyckhuys, 2021).

Obtaining data from all arthropods, many which are small, short lived and cryptic over is complicated and costly (Åström et al., 2020). The recent Swedish malaise trap project (Karlsson

et al., 2020) illustrates the point: arthropods were collected in 55 locations over 3 years, 15 years and 30 million Swedish kroner later they have only been able to identify 1% of the 20 million individuals they caught. It is therefore common to focus on smaller taxonomic groups, or lower resolution data such as arthropod orders in monitoring studies, although the variation in response to different environmental variables within the order will then be lost. Changes in a specific taxonomic group can have significant impact on important ecosystem functions and direct effect on vertebrates that depend on that specific taxon as a food source. Future studies of arthropods should therefore include lower resolution biomass, i.e., at least taxonomic order specific biomass.

The reported declines of arthropod biomass, abundance and species richness are suspected to be cause mainly by human interference and land-use practices (Seibold et al., 2019). Climate change, exotic species, fragmentation, deterioration of habitat quality and forest management has been proposed as some of the factors causing the declines (Hallmann et al., 2017). Reports of insect declines also include forested areas (Hallmann et al., 2017; Seibold et al., 2016; Seibold et al., 2019), and forestry management practices play a large role here. As many as 60% of Norwegian species live in forests, and 41% of these are negatively affected by forestry (Henriksen & Hilmo, 2015). Forests cover 37% of the land surface in Norway, and Norway has an extensive history of forest management.

Clear-cutting is the most common forest management practice in Norway today (Bartlett et al., 2020). A quarter of forest dwelling species depend on dead wood (Speight, 1989), and clear-cutting has been found to drastically reducing dead wood availability sometimes with up to 98% (Jacobsen et al., 2020; Økland et al., 1996; Seibold et al., 2016). Clear-cutting also changes other forest stand characteristics such as forest age spread, tree species composition, deadwood concentration and decomposition stages as well as canopy openness and micro-climate (Burner et al., 2020; Seibold et al., 2016). Forests which have not been clear-cut or regenerated by planting can be called near-natural forests, similarly to old growth forests they have trees in all age groups and high percentages of dead trees in varying sizes and decomposition stages. Estimates from 2016 show that only about 30% of Norwegian forests can be called “ near natural forests” (Storaunet & Rolstad, 2020) and this number is expected to further decline in the future

(Storaunet & Rolstad, 2015; Wegge & Rolstad, 2018). A meta-analysis where 49 papers comparing biodiversity between managed and unmanaged forests in Europe revealed a loss in species richness of 6.8% in the managed forests (Paillet et al., 2010). There are also studies documenting lower diversity among beetle communities in managed forests (Jacobsen et al., 2020; Lange et al., 2014; Paillet et al., 2010).

Preserving arthropod abundance and diversity should be a conservation priority, and more knowledge is needed on the effects of human interference on arthropods and their habitat. To achieve this, arthropod monitoring studies are needed. These types of studies commonly use a mass-sampling strategy consisting of malaise traps, as they catch a broad spectrum of insects and significantly more individuals than any other trap (Åström et al., 2020; Hallmann et al., 2017). There are different variations of malaise traps available, the overall design principles remain the same, although the color and size may vary (Åström et al., 2020; Malaise, 1937; Sheikh et al., 2016). It is shaped much like a human tent, made from a fine-mesh material with a dividing wall in the center. The idea is that the flying insect will fly towards middle of the tent, reach the central middle wall and follow it up, ever higher, until the tent narrows at the top where a bottle is attached with a killing agent to capture the insects (Sheikh et al., 2016). Malaise traps excel at catching small flying insects, especially Dipterans and Hymenopterans (Karlsson et al., 2020). The larger insects with good vision such as dragonflies and butterflies can evade it (Karlsson et al., 2020). It also catches some wingless arthropods that crawl up into it or are blown by the wind, such as spiders, mites and springtails (Karlsson et al., 2020).

Arthropods is a species-rich group with a wide diversity of functional traits and habitat preferences, which means a variety of sampling techniques is required for monitoring a population. Specific traps are often used to target a subset of taxa (Burner et al., 2020; Didham et al., 2020; Lebuhn et al., 2013). Window traps for example are known to have the highest capture rate of large beetles, a well-studied and species-rich group in forests, they provide important ecosystem functions like nutrient cycling, decomposition and predation (Ulyshen et al., 2018). Beetles respond quickly to habitat changes have been used in several studies that compare effects of forest management in Europe (Jacobsen et al., 2020; Lange et al., 2014; Müller et al., 2015; Paillet et al., 2010). Their diversity makes it challenging accurately sample them because of the

high frequency of rare species (Burner et al., 2021). Currently window traps do not yet have a standardized design (Bouget et al., 2009; Burner et al., 2020). Most window traps are made up of three parts: A single transparent panel or two crossed panels which the flying beetles will collide and hit the panel, a funnel with a bottle attached which the beetle will subsequently fall down into and drown and a lastly roof to keep the rain out. Window traps come in all sizes, shapes and colors and materials and this can be problematic as the effectiveness of different trap designs are known to vary (Burner et al., 2021; Siitonen, 1994). A couple of studies have compared the beetle capture rates and beetle diversity sampled between different window trap types (Allison & Redak, 2017; Bouget et al., 2008; Burner et al., 2020; Burner et al., 2021), but biomass was not included in any of the studies.

Insects respond not only to macroclimate and large-scale land use, but also to local habitat conditions as well as humidity and temperature (Jacobsen et al., 2020; Paillet et al., 2010). In addition to the decline of the total insect biomass, is it therefor also important to study the effects and relative contribution of certain proposed factors such as temperature, climate, forest habitat variables such as deadwood volume and diversity and management practice to understand the drivers behind the declines (Seibold et al., 2019).

The main objective of this thesis is to investigate biomass and abundance of local arthropod communities in southeastern forests in Norway, and if forest management practices have any effect. This will be done by a mass sampling of arthropods using multiple malaise traps in five pairs of forests consisting of a mature previously clear-cut forest (CC) site and mature near-natural forest site (NN). I specifically ask (i) does arthropod biomass and/or abundance vary between the CC and NN forest sites and which forest characteristics determined by forest management help in explaining the variance, and (ii) are differences in abundance or biomass with forest management independent of taxonomic order? Lastly, I will compare three different window trap types and one malaise trap type to find out which are the most efficient at catching beetles. My last question is (iii) how do the trap types vary in terms beetle abundance and biomass caught.

2 Materials and methods

2.1 Study area and design

This study is a part of EcoForest: "Forestry effects on biodiversity, carbon stock and ecological processes in mature boreal forests" financed by the Norwegian Research council and the location of the insect sampling sites were largely determined by the study design of the original project. The study locations were selected firstly according to historical records/aerial images of clear-cuts (CC) and near-natural (NN) sites. Further site selection criteria were: the NN- and CC-site pair should be less 5 km apart and have approximate equal vegetation type, productivity, soil profile levels, southward-facing aspects, and similar variation in canopy gaps.

Five study locations were used in this study; Østmarka (OST), Lunner (LUNN), Varaldskogen (VAR), Våler (VAL) and Gravberget (GRAV) (*Fig.1)*. The sites are located in south-eastern Norway close to the Swedish border. All sites were mature boreal forests dominated largely by Norway spruce (*Picea abies*), some Scots pine (*Pinus sylvestris)* and more rarely birch (*Betula pubescens*) and rowan (*Sorbus aucoparia*).

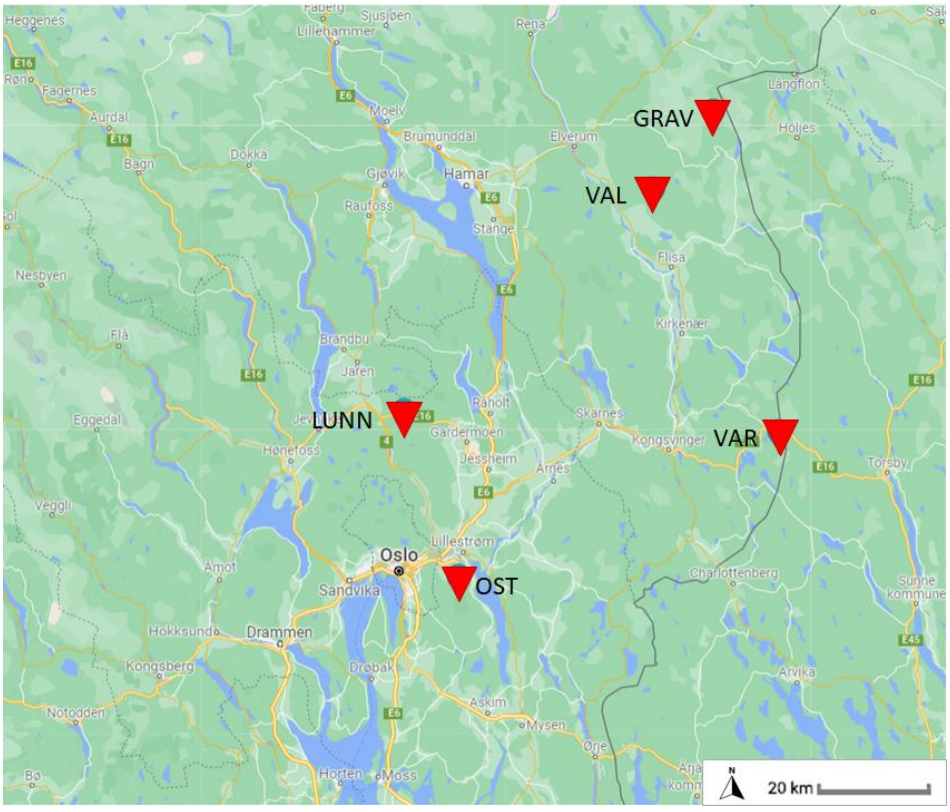

Figure 1 The five study locations in the project; Østmarka (OST), Lunner (LUNN), Varaldskogen (VAR), Våler (VAL) and Gravberget (GRAV). Each site consist of a pair of near-natural (NN) and clear-cut forest (CC). Map created with Google Earth.

Each of the five study locations consisted of one clear-cut forest site (CC) and one near-natural site (NN), making it 10 sites in total (Fig.2). In each site (NN or CC) four groups of insect traps were put up, and each group had in total 6 window traps and one malaise tent (Bugdorm, Taiwan) except for one group that was without a malaise tent. This configuration of traps results in a total of 24 window traps and 3 malaise tents at each site (Fig.2). The high number of traps per site should ensure efficient arthropod sampling. The coordinates for each trap group are listed in Appendix 1.

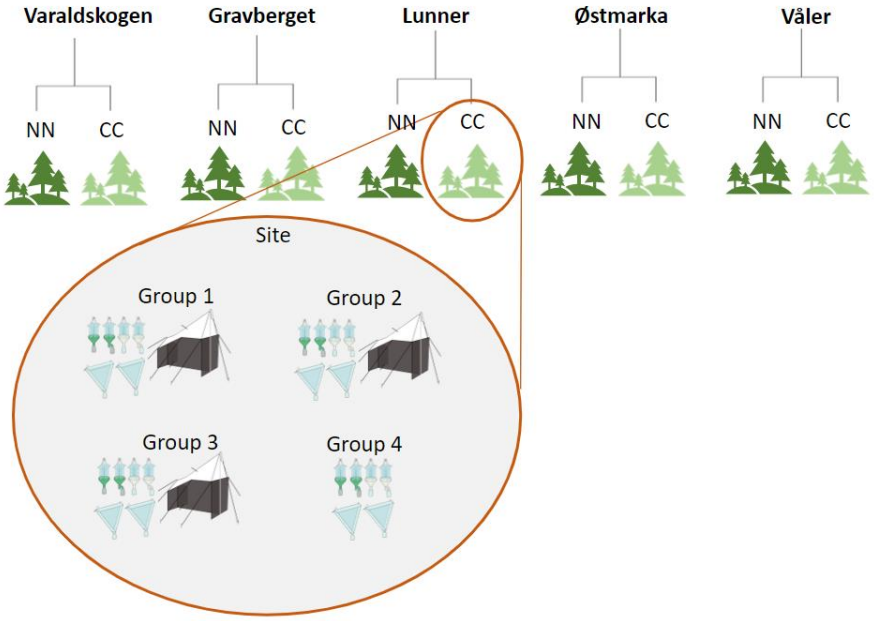

Figure 2 The study design, consisting of 5 study locations with a clear-cut (CC) and near-natural (NN) forest pair. In each site (either NN or CC) there are four trap groups with 6 window traps and in three groups there is a malaise tent, making a total of 24 window traps and 3 malaise tents in one site.

Trap-group within the site had the following placement criteria: traps placed directly by pieces of deadwood, maximum sunlight reaching the traps, 2-5m between traps in a group, and 20-50m between trap-groups (Fig. 3). Window traps were hung up on a string between trees at about 1.5m height above ground. The malaise was attached to a small tree, with the base touching the forest floor (Fig. 3).

Figure 3 Example of trap configuration showing the complete set up of a trap group with six window traps and one malaise tent.

2.3 Arthropod sampling

All traps were activated between the 26th and 28th of July and the traps were emptied between the 1st and 3rd of September, having an active trapping period of 5 weeks and 2 days. The Ostmarka site, had an additional trapping period between the 29th of June and the 26th of July with an active period of 4 weeks. This additional trapping period in Ostmarka allows us to see whether any differences in arthropod biomass and counts found in the august trapping period were representative for earlier trapping periods as well. Ideally, I should have had two trapping periods for all sites, but the site selection process was not finished before end of July. (See appendix 2, for trap activation schedule).

This study used two types of window traps: a custom made cross-pane trap and triangular single pane IBL-2 trap produced by CHEMIPAN (Warsaw, Poland). The custom made cross-pane window traps included four variants: two with a water module to divert rainwater and two

without, and one green and one white in each category (Fig.4). The color variants were excluded as there was no difference, and simply treated as duplicates with or without water modules (Fig.4). The triangular IBL-2 traps had a capture surface of 3950 cm^2, and the cross-pane window traps a surface of 1600 cm^2. I also included malaise tents (Bugdorm, Taiwan), as they are good for mass trapping of flying insects and catch a great variety arthropods.

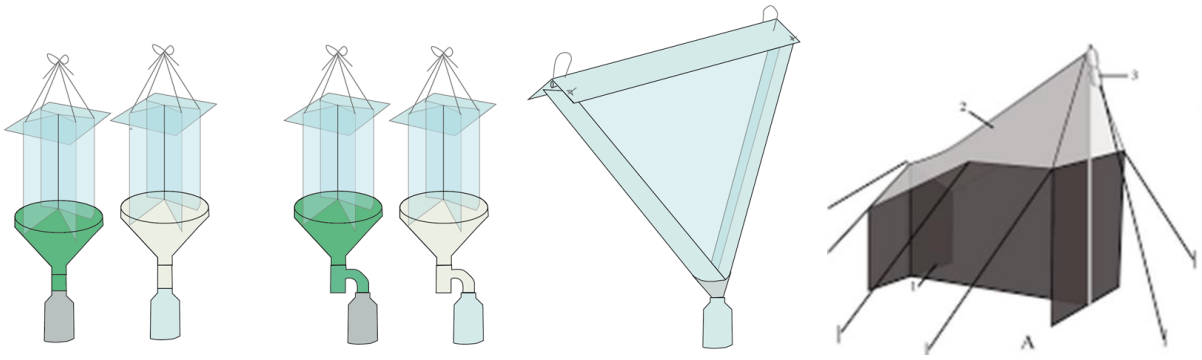

Figure 4 The trap types used in the project in order from left to right green and white cross-pane window traps (W), green and white cross-pane window traps with water module (WM), triangular IBL-2 window trap and lastly a malaise tent.

Window trap sampling bottles were filled with a mix of 70% prop glycol + 30% ethanol (already diluted at 85%) and the malaise trap bottles had a mixture of 85% ethanol (96% ethanol diluted with water). Trap contents were stored in freezer until lab processing.

2.4 Environmental variables

Around each trap group a 25x25m square was measured out. First, a central point was picked from which distances of 17.7m were measured out in opposite directions making an X formation and red flagging was used to mark the corners of the square. I used a relascope at the central point to measure the canopy openness represented by basal area. I measured the volume of all standing and laying deadwood that were rooted within the plot, if it had a DBH (diameter at breast height) of at least 10cm and was longer/taller than 0.5 m (this was done to eliminate stumps left after logging). For each dead tree I measured the bottom diameter, the DBH and the top diameter (with a cut off at 5 cm). The length/height was measured from bottom of the trunk

to the top point where the trunk diameter reached 5 cm. For each dead tree I also noted the tree species, if it was coniferous or deciduous, if it was a log or a snag and the decay class (more below).

The decay class of each dead tree was determined by using a knife and penetrating the trunk in different places. The classes are modified by (Lilja et al., 2006) and first described by (Renvall, 1995): (I) freshly dead, a tree that has died during the last year, needles usually still attached; phloem under bark still light in color or currently used by bark beetles, (II) hard, a knife penetrates by pushing only a few millimeters into the wood, >50% bark remaining, (III) soft surface wood, knife penetrates 1–2 cm, <50% bark remaining, (IV) relatively soft, knife penetrates 3–5 cm, <50% bark remaining, (V) soft throughout; knife penetrates all the way, often fragmented and partly buried into the ground.

The deadwood volume of each log calculated using the Huber's formula

$$Volume = \frac{\pi}{4} * L * \left(\frac{D_1 + D_2}{2}\right)^2$$

where L is the length of log (m), D_1 is the bottom diameter of log (m), and D_2 is the top diameter of log (m). The volume is then given in cubic meters.

The deadwood diversity within each plot was calculated using the Shannon Index (H) as outlined by (Oettel et al., 2020). A similar technique of using the Shannon Weiner index for stand structure was also used by Boucher et al.(2006). The diversity of deadwood was analyzed with (1) species, (2) diameter class, (3) degree of decomposition (decay class), and (4) quality of deadwood. The DBH measurements were divided into three classes: small (10-20cm), medium (20-30 cm), and large (30+cm).

$$Deadwood\ diversity = -\sum_{i=1-n}^{n} P_i * log_2 * p_i$$

where p_i is the proportion of the i^{th} species, diameter class, decay class or type. Higher diversity is indicated with higher numbers.

A temperature logger (Tinytag, TGB-4017) was put up in each trap group which measured hourly temperature. Mean day temperature was retrieved using Tinytag data logging software and processing the data in R. The mean day temperature was calculated by first finding the mean day temperature between 06:00 and 22:00 for each day and then calculating the average mean day temperature of measuring days for each trap group.

2.4 Laboratory Processing

The main part of the laboratory work was spent on sorting the arthropods from the malaise traps into different arthropod orders and some taxonomic subgroups of interest, then each group was counted and the wet weight was noted. From the window traps samples, only the beetles were picked out from each sample, counted and wet weights were taken. A detailed description of processing samples from malaise traps is described below.

Processing sample from malaise traps included first removing it from the freezer, pouring it through a fine metal sieve to drain out the preserving liquid putting the arthropods in a large petri dish. The arthropods over 4 mm in body length, were picked out individually using tweezers, putting them in a glass vial for each order or sub-order while keeping count. I decided on sorting them into each order (16 in total (including Gastropoda and Chilopoda which are classes). For the orders which I could easily identify sub orders, Hymenoptera and Diptera, I did so. The Hymenoptera order was split into Symphyta, 'Parasitica' and Aculeata, and each of these had several more subgroups, see appendix 3 for complete list. Dipterans were split into either Nematocera or Brachycera, and then further split into Tipulidae or Syrphidae respectively. At the end of the first processing, the arthropods sampled from one trap should be counted sorted into different glass vials according to the determined order or suborder. The vials were filled with 80% ethanol to preserve, while processing the rest of the samples.

I caught a lot of small individuals under 4mm, and these were left in the petri dish when all larger individuals had been picked out. To save time I distributed the small individuals equally

and counted each arthropod order in a quarter of the petri dish, the number was then multiplied by four. Our small individuals consisted mainly of small Dipterans, parasitic wasps and springtails and mites. I started counting the the Acariformes manually, but I soon realized it would not be possible within out time frame and the error margin would be quite large due to their size and abundance, so they were excluded from the results. The biomass of the small individuals was determined using the order specific formula from Sample et al. 1993:

$$Biomass\ (g) = \frac{(e^b * X^a)}{10}$$

Where e= 2.71828, X= body length in mm, and *b* and *a* are order specific numbers given in a table by (Sample et al., 1993).

Once all samples were sorted, the wet weight of the orders/sub orders with individuals > 4mm was determined using the wet weight procedure outlined by Hallmann et al., 2017. A vial was designated for each functional group and weighed on a precision scale. Then, the contents of a vial were poured into stainless steel sieve with 0.8mm mesh with at a 30-degree angle over a petri dish and placed into the vial. The arthropods were picked up and put into the previously weighed empty vial and the vial and insects were then weighed. The weight from the vial alone was subtracted from the vial and insects to determine the wet weight.

2.5 Data Analysis

All collected samples (n=323) were used in the data analysis. The data was analyzed using R version 4.0.4 and RStudio version 1.4.1717.

To determine the effects of the predictor variables on arthropod biomass and abundance, a Bayesian mixed model was used from the R package ‘lme4’ (Bates et al., 2015) with site and trap group number included as random effects with a random intercept on the data from the malaise traps. Both the biomass and abundance were log-transformed due to higher numbers of

low weights and low counts, to obtain a normal distribution.

I started out with the following full Bayesian mixed model models, in R:
lmer (log(Biomass) ~ Forest management + Temperature + Openness + Deadwood volume + Deadwood diversity + (1 |Site / Group))
lmer(log(Abundance) ~ Forest management + Temperature + Openness + Deadwood volume + Deadwood diversity + (1 |Site / Group))

I then removed predictor variables one by one while observing the AIC and VIF in the 'car' package (Fox & Weisberg, 2011) and R^2 from the 'lmerTest' package (Kuznetsova et al., 2017) to determine the best models. The predictor variables were not highly correlated (VIF < 1.5). I used the same procedure on the two trapping periods of malaise traps from Østmarka to see the effect of the two trapping periods, and to see whether any predictors were stronger now that landscape and site variables were eliminated. I had to replace 'Temperature' from the model above with 'Month' as the two were highly correlated and I could only keep one. To investigate how the predictor variables affected the different arthropod orders, I subsetted each order and used the same procedure as mentioned above, testing the full models with biomass and abundance and eliminated predictors to get the best model.

When comparing the efficiency of the trap types of beetle capture, the two trapping periods were merged. As mentioned earlier, I saw no difference in capture rates between the two colour variants of the cross-pane window traps, so the ones with module were treated as equal (here after called WM) and the cross-pane window traps without water module were treated as equal (here after called W). To check for differences in capture by the trap types, I first ran Levene's test also from the 'car' package (Fox & Weisberg, 2011) to check for homogeneity of variance, an important assumption to be able to use ANOVA. Then a one-way ANOVA was run to test for differences in both mean beetle biomass and mean beetle count per trap. A Tukey's Honestly Significant Difference (Tukey's HSD) post-hoc test was then run to reveal which traps were significantly different from each other by doing pairwise comparisons between the trap types.

3 Results

From our 35 malaise traps from both August and July, 31 719 arthropods were counted making up a total biomass of 285 grams. The July trapping period (consisting of only 6 malaise traps) made up about a third of the arthropods with a count of 9190 and a biomass of 88 grams. All our 288 window traps combined caught 5792 beetles weighing a total of 94 grams, with about half of those (2551) being caught in July, by 48 window traps with a total biomass of 29 grams.
The individuals from the malaise traps consisted mostly of dipterans (36%), hymenopterans (21%) and collembolas (29%), the other arthropods together make up 15% (fig.5). Although few lepidopterans and opiliones were caught, they each make up a relatively large percentage of the total biomass caught (22% and 12% respectively, fig.5).

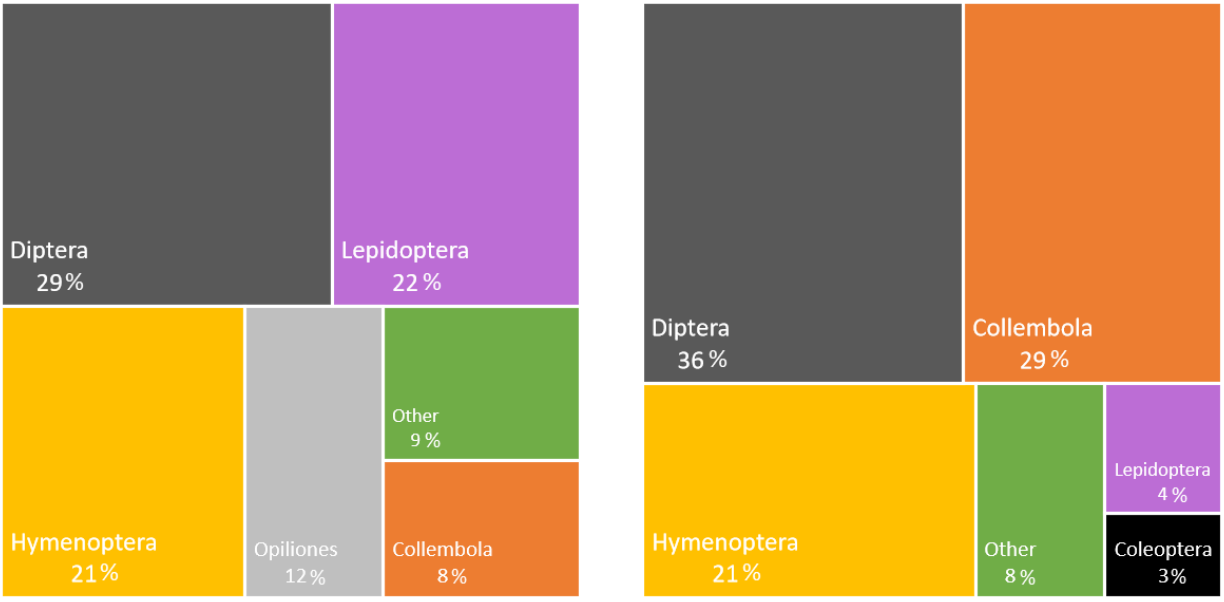

Figure 5 Overall catch composition of malaise traps, biomass (g/wet) to the left and abundance to the right.

3.1 Predictors of arthropod biomass and arthropod abundance of malaise traps

The best model for predicting arthropod biomass and abundance using all sites combined included the predictor variables 'forest management', 'deadwood volume' and 'deadwood diversity' (Table 1). Forest management was the only significant predictor, showing a lower estimate for both arthropod biomass and abundance in CC forest compared to NN forest (Table 1, Fig. 6). Deadwood volume was a weak negative predictor for arthropod biomass (p=0.074). The marginal R^2 were low and explained only 1.7% and 1% respectively of variation of biomass and count data (Table 1).

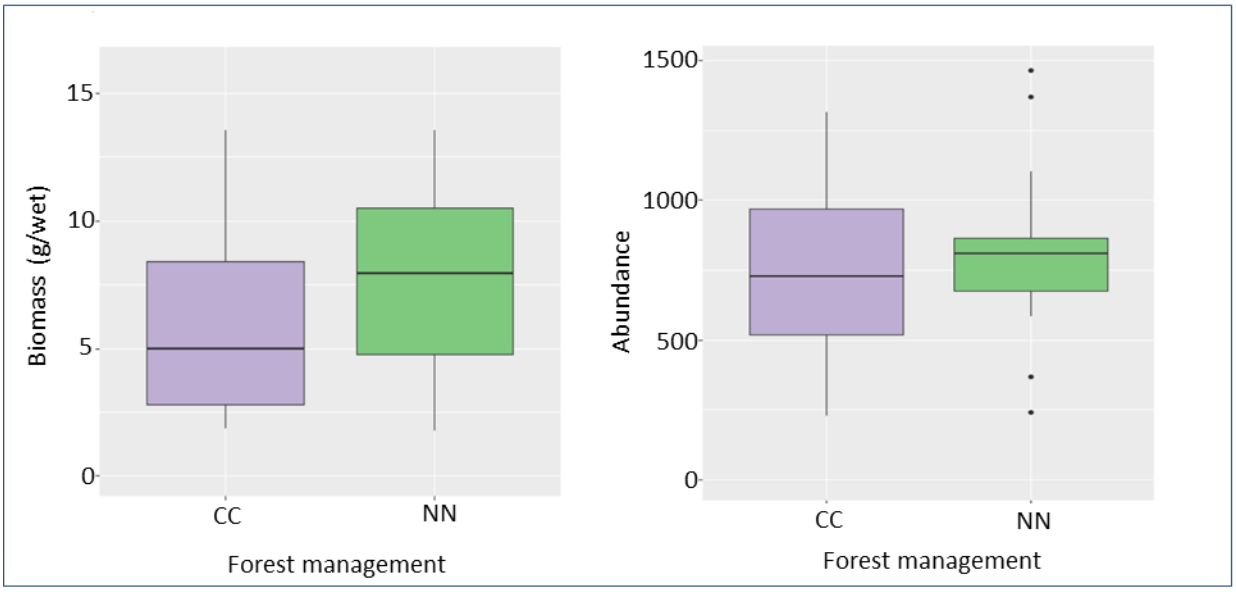

Figure 6 Boxplot showing distribution of biomass (left) and abundance (right) from malaise traps in clear-cut (CC) (n=15) and near-natural (NN) (n=15), in August 2021. The means were significantly different according to linear mixed model, p=0.012 for biomass and p=0.037 for number of arthropods (Table 1). Boxes represent data within the 25th and 75th percentile, and black lines show medians and whiskers show 1.5x the interquartile range.

Table 1 Predictor estimates for arthropod biomass and abundance, derived from a linear mixed model. Forest management compares former mature clear-cut forest to mature near-natural forest. Deadwood volume is the average of the total deadwood volume of the four 25m^2 plots of each site, measured in m^3. Deadwood diversity describes how diverse the deadwood is (higher is more diverse). Marginal R^2 shows the percentage of variance the fixed effects (predictor variables) explain. Significant p-values are marked in bold.

	Biomass (g/wet)					Abundance				
	Estimate	SE	t-value	p	R^2	Estimate	SE	t-value	p	R^2
Forest management	-0.966	0.675	-2.515	**0.012**		-0.194	0.092	-2.09	**0.037**	
Deadwood volume	-0.043	0.024	-1.791	0.074		0.038	0.025	-1.516	0.191	
Deadwood diversity	0.433	0.346	-1.261	0.208		0.08	0.369	-0.217	0.465	
					0.017					0.010

In order to test whether the data from our main catch is representable, as there are less flying insects in August, I also tested the seasonal effects on the Østmarka data (three malaise traps in NN-site and three in CC-site). Østmarka is the only site that had active traps in both July as well as August. Similar to the main catch from all sites, Østmarka showed biomass in the NN-site compared to the CC-site (p= 0.001, Fig.7, Table 2). The abundance was also higher in the Østmarka NN-site compared to the CC-site, but this effect was only close to significant (p= 0.090). In addition, in Østmarka high biomass was predicted by low deadwood volume and the same effect was seen for abundance but only close to significant (p= 0.064). As expected, there was higher arthropod abundances in July compared to August. The models for Østmarka better explained arthropod biomass and abundance, due to less noise of only having one site (R^2 of 91.5% and 65.4% respectively, Table 2).

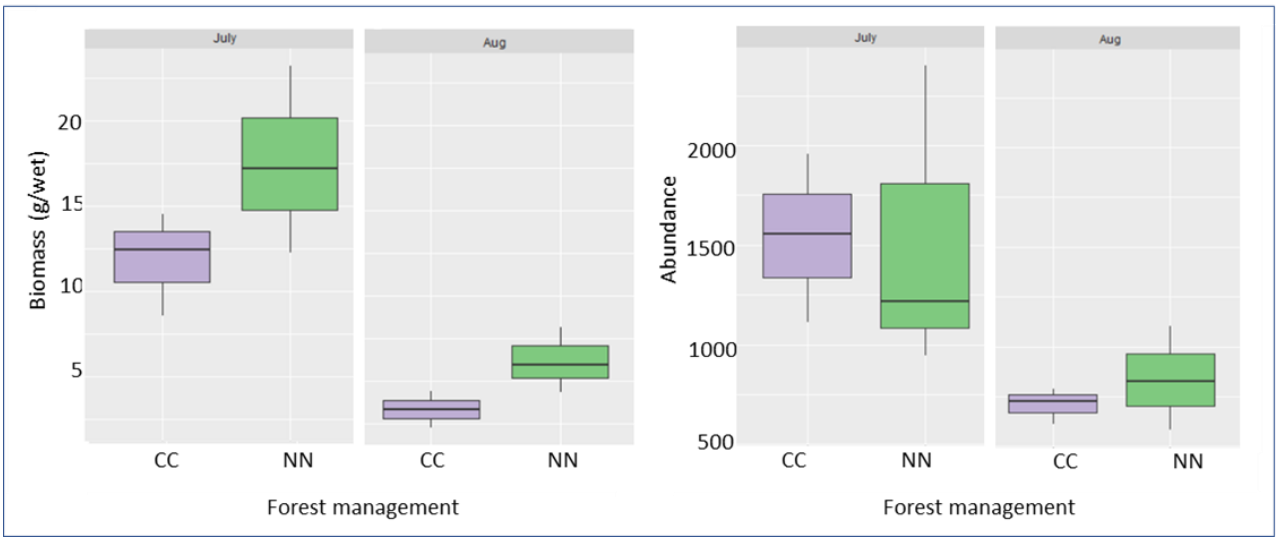

Figure 7 Arthropod biomass (left) and abundance (right), from malaise traps in the Ostmarka CC- and NN-forests, split into the two trapping periods 'July' and 'August'. Each box contains n=3 malaise traps. Significant differences are shown in Table 2.

Table 2 Predictor estimates for arthropod biomass (g/wet) and abundance in Ostmarka. Forest management compares CC forest to NN forest. Deadwood volume is the average total deadwood volume of the four 25m² plots at each site, measured in m³. Deadwood diversity describes how diverse the deadwood is (higher is more diverse). Marginal R^2 shows the percentage of variance the fixed effects (predictor variables) explain. Significant p-values are marked in bold.

	Biomass (g/wet)					**Abundance**				
	Estimate	SE	t-value	p	R^2	Estimate	SE	t-value	p	R^2
Forest management	-0.411	0.077	-5.283	**0.001**		-0.121	0.114	-1.067	0.090	
Deadwood volume	-0.139	0.040	-3.603	**0.007**		-0.070	0.052	-1.506	0.064	
Month	-0.596	0.051	-11.504	**< 0.001**		-0.315	0.087	-3.633	**0.011**	
					0.915					0.654

3.2 Difference in predictors of biomass and abundance for specific arthropod orders

Biomass and abundance in the different arthropod orders were explained by different predictor variables, and some orders varied in their response to forest management (Table 3). Most orders had lower estimated biomass in CC forest vs. NN forest (see 'Forest management'), although not all were significant. The following arthropod orders had lower biomass in CC-forests: Collembola, Gastropoda and Lepidoptera. The Diptera and Aranea showed the inverse relationship with a higher estimate of biomass in the CC forest compared to the NN forest. Diptera was also the only order for which biomass increased with lower deadwood volume. (Table 3).

The following orders had higher predicted abundance in NN forest: Collembola, Hymenoptera, Lepidoptera and Trichoptera. Diptera and Araneae on the other hand, had higher estimated abundance in CC-forest compared to NN-forest. Forest management, deadwood volume, canopy openness and temperature all predicted Diptera abundance. Coleoptera abundance significantly increased with canopy openness. Collembola significantly increased with higher temperature. (Table 3).

3.3 Trap type comparisons and beetle capture

Significant differences in mean biomass caught of each trap types was revealed with one way ANOVA ($F(3, 319) = 36.98$, $p < .001$). The Tukey post hoc test revealed that the Polish IBL window trap caught on average 0.44g more than the malaise trap, 0.58g more than the window traps with water module and 0.53g more than the window trap without water module (Fig.8, Table 4).

One way ANOVA results also showed significant difference in mean beetle abundance between trap types ($F(3, 319) = 57.03$, $p < .001$). The Tukey post hoc test revealed that the Polish IBL window trap caught 23.98 more beetle individuals than the malaise trap, 46.03 more beetles than the window trap with water module and 42 more beetles than the window trap without water

module (Fig.8, table 4). In addition, the malaise trap caught 22 more beetle individuals than the window trap with water module and 18 more beetles that the window trap without water module (Fig.8, table 4).

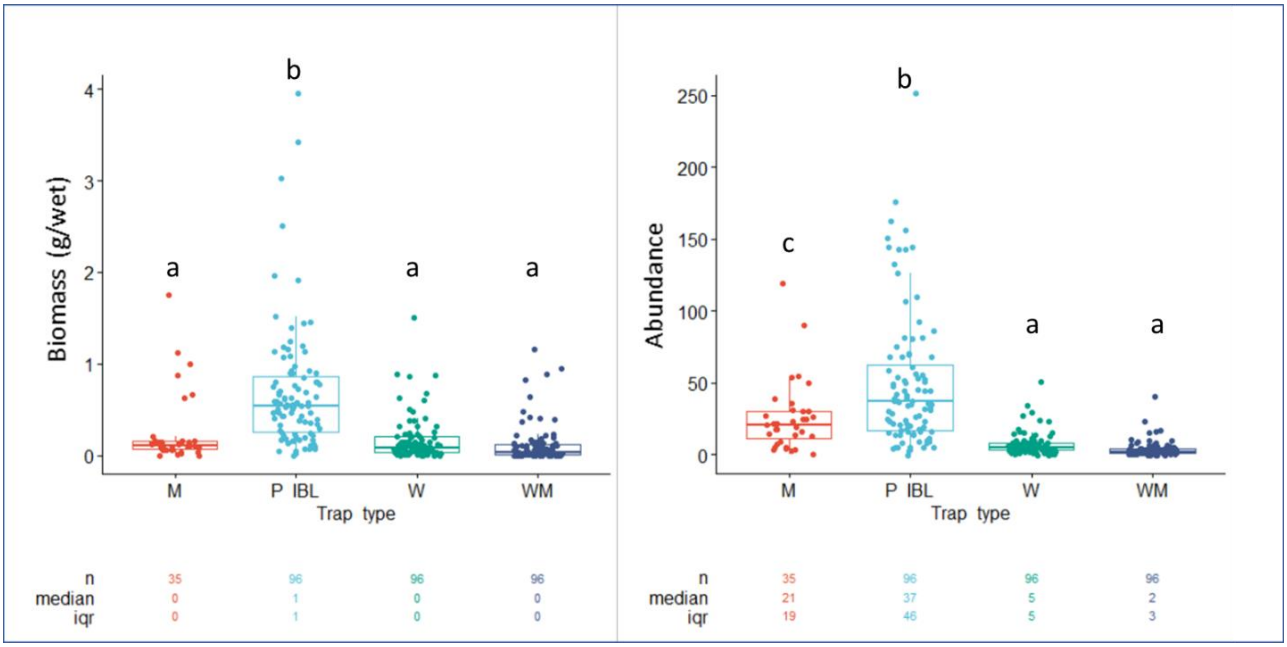

Figure 8 Trap types and beetle biomass (left), and beetles counts (right). M= malaise trap, P IBL= Polish IBL trap, W= window trap without water module and WM= window trap with water module. Difference in letters between trap types indicate significant differences of trap means by ANOVA and Tukey post hoc tests. Below the boxplot, n stands for number of traps for each trap type and interquartile range is the spread of the middle 50% of the data(iqr).

Table 3 Predictor estimates for arthropod biomass and count per arthropod order from GLM. DW volume (deadwood volume), DW div (Deadwood diversity), Openness (Canopy openness), Temp (mean day temperature in Celsius). Marginal R^2 shows the percentage of variance the fixed effects (predictor variables) explain. Stars indicate significant p-values.

	Biomass (g/wet)						Abundance					
Order	Forest management	DW_div	DW_vol	Openness	Temp	R^2	Forest management	DW_div	DW_vol	Openness	Temp	R^2
Araneae	0.046 (*)	0.178 (*)		-0.003 (*)	-0.297	0.281	1.375 (*)	4.629	-0.254	-0.104		0.183
Coleoptera	-0.245		-0.110			0.084	-0.087		-0.042	0.034 (*)		0.139
Collembola	-0.470 (*)	-1.500	0.04		0.889 (*)	0.37	-0.476(*)	-1.616			0.862 (*)	0.319
Dermaptera	-1.896			0.015	-0.173	0.110	-0.465	-0.845	-0.071	0.014	0.382	0.165
Diptera	0.373 (*)	0.581	-0.216 (**)	0.016		0.277	0.213 (*)		-0.080 (*)	0.021 (*)	0.195(*)	0.371
Gastropoda	-0.542 (*)	-2.998 (*)	-0.018	0.075 (*)	-0.599 (*)	0.750	-0.056	-0.875	-0.220 (*)	0.056 (*)		0.416
Hemiptera	-0.102		0.023	-0.018		0.041	-0.141		0.034	-0.007		0.044
Hymenoptera	-0.063		0.079	-0.026		0.076	-0.244 (*)					0.059
Lepidoptera	-0.452 (**)		0.055		-0.203	0.151	-0.246 (**)		0.348	-0.183	-0.868	0.21
Neuroptera	-0.327		0.018	-0.022		0.230	0.005		-0.105	0.055		0.163
Opiliones	-0.006		0.085	-0.049 (**)		0.220	-0.116					0.009
Psocoptera	0.331		-0.088	-0.016	-0.393	0.238	6.157		-2.796	-0.618	-7.263	0.221
Trichoptera	-0.014		-0.002	0.001		0.203	-0.577 (*)		-0.085	0.014		0.443

Table 4 Differences in mean arthropod biomass (left) between trap types and differences of mean abundance (right), from One way ANOVA with Tukey HSD post hoc test. Traps are malaise (M), Polish IBL window trap (P IBL), cross-pane window trap without water module (W) and cross-pane window trap with water module (WM). 95% confidence intervals are reported as well as p-values. Significant p-values are marked in bold.

ANOVA BIOMASS						ANOVA ABUNDANCE					
Trap comparison		Mean difference	p	95% Confidence interval		Trap comparison		Mean difference	p	95% Confidence interval	
				Lower	Upper					Lower	Upper
	P IBL	-0.447	**< 0.001**	0.230	0.666		P IBL	-23.984	**< 0.001**	-37.910	-10.059
M	W	0.084	0.752	-0.134	0.302	M	W	18.745	**0.003**	4.821	32.670
	WM	0.136	0.367	-0.081	0.355		WM	22.047	**< 0.001**	8.123	35.972
	M	0.447	**< 0.001**	0.230	0.666		M	23.984	**< 0.001**	10.059	37.908
P IBL	W	0.532	**< 0.001**	0.373	0.691	P IBL	W	42.729	**< 0.001**	32.550	52.907
	WM	0.585	**< 0.001**	0.426	0.744		WM	46.031	**< 0.001**	35.852	56.210
	P IBL	-0.532	**< 0.001**	-0.691	-0.373		P IBL	-42.729	**< 0.001**	-52.907	-32.550
W	M	-0.084	0.752	-0.302	0.134	W	M	-18.745	**0.003**	-32.670	-4.821
	WM	0.053	0.826	-0.106	0.212		WM	-3.302	0.836	-13.481	6.877
	M	-0.136	0.367	-0.355	0.081		M	-0.136	0.367	-0.355	0.081
WM	P IBL	-0.585	**< 0.001**	-0.744	-0.426	WM	P IBL	'-0.053	**< 0.001**	-0.744	-0.426
	W	-0.053	0.826	-0.212	0.106		W	-0.053	0.826	-0.212	0.106

4. Discussion

4.1 Forest management effects on arthropods

To my knowledge, this is the first study comparing arthropod biomass between two forest management types in Norway. Previous studies have shown higher species diversity and lower decline rates in less managed forests both in Norway and Europe compared to more intensely managed forests (Jacobsen et al., 2020; Seibold et al., 2019). My results show that clear-cutting has a significant long-term impact on both arthropod biomass and abundance, as the difference is even 70-years after the clear-cutting took place. Overall, the CC-sites had lower biomass and abundances compared to NN-sites. This pattern was true when including data from July, although the abundance was only approaching significance ($p=0.09$). This shows that intense forest management practices such as clear-cutting do not only affect beetle species richness as previously shown (Jacobsen et al., 2020) but it also affects the abundances and accumulative biomass of arthropods in general.

I found that the response of different arthropod orders to intense forest management varied greatly between taxonomic orders. Nevertheless, my study showed that Collembola, Gastropoda, Lepidoptera, Hymenoptera and Trichoptera had higher biomass and/or abundance in the NN-sites compared to the CC-sites (as expected), while Diptera and Aranea showed the opposite. However, it is likely that there are opposite trends within subgroups of the different orders making it difficult to see the true effects. My trap-groups were placed near clusters of deadwood in order to attract saproxylic arthropods, which are the ones threatened by intensive forest management (Ulyshen et al., 2018). However, the arthropods were not identified to species level and the fraction of saproxylic arthropods in our catch remains unknown. Many studies have focused on beetles, and the effects of forest management on saproxylic beetles or carabid beetles have been well studied (Brin et al., 2011; Brooks et al., 2012; du Bus de Warnaffe & Lebrun, 2004; Jacobsen et al., 2020; Lange et al., 2014). The effects of forest management on arthropod orders aside from beetles is lacking (Raymond-Léonard et al., 2020; Seibold et al., 2015). Thus, studies addressing the effects of forest management on other arthropod orders are urgently needed (Raymond-Léonard et al., 2020; Stokland et al., 2012; Ulyshen et al., 2018).

Although few studies have examined habitat preferences for collembola, they seem to have strong preference for less managed forests. There is a lack of knowledge on springtails regarding particular habitats in forests (Mladenovic et al., 2021; Raymond-Léonard et al., 2020). The majority of Collembola species are decomposers (Shayanmehr et al., 2005) and saproxylicity is a part of keystone processes of nutrient cycling and decomposing (Mladenovic et al., 2021). Despite the abundance and importance of springtails, the number of saproxylic species remains largely unknown as they are mostly studied in the soil or litter layer (Raymond-Léonard et al., 2020). A study of springtails in natural forests in Canada found that 74 out of 168 known regional springtail species used deadwood as habitat, and that non-saproxylic springtails also use deadwood as habitat (Raymond-Léonard et al., 2020).

I found a similar strong preference for near-natural forest over clear-cut forest in lepidopterans. Most adult lepidopterans are not saproxylic, and the larvae and adults have distinctly different niches and habitat requirements (Krenn, 2010). A study in mixed forests of Ohio (US) found that species richens of adult lepidopteran communities and larvae feeding guilds were significantly lower in clear-cut stands compared to selectively logged and unlogged stands (Summerville & Crist, 2002). Another study of nocturnal lepidopterans in mixed forest in Germany found that the relative abundance of moths of the saproxylic and detritus-feeding larval guilds was higher in natural forest stands compared to logged forest stands (Thorn et al., 2015). Besides the differences in the supply of dead wood, near-natural forests are often more open and multi-layered and include both a ground- and shrub-layer vegetation which are often missing in previously clear-cut forests. The increasing biomass of herbaceous plants in turn promotes the relative abundance of numerous lepidopteran species (Thorn et al., 2015), and could explain why I found more lepidopterans in the near-natural forests.

Shifts in composition of Diptera in intensely managed forest sites could explain why I found more Dipterans in CC-sites. Diptera is one of the four most taxonomically diverse orders, and individuals are rarely identified to species level due to poor knowledge about them and the level of difficulty (Karlsson et al., 2020). Subgroups within Diptera have different functional traits and habitat preferences and saproxylic individuals are known from at least 48% of the fly families (Ulyshen et al., 2018). Ulyshen et al. (2018) stresses that saproxylic fly species are

declining and that studies which addresses their sensitivity to forest management are urgently needed. Hence there is a shift from (specialist) saproxylic groups to generalists as a result of clear-cut forestry. It known that habitat change can lead to shifts in the population compositions, and disturbances often favor species which can compensate declines with abundance, i.e., invasive species and potential pests (Seibold et al., 2019). Since the dipteran abundance in my study was greater on the CC sites, this trend in increasing generalists could be relevant. Future studies of Dipterans and forest management should include lower taxonomic groups, as close to species level as possible to confirm this.

I found that deadwood volume varied greatly between NN- and CC- forest sites. Deadwood volume correlated negatively with arthropod biomass in the Østmarka dataset and only nearly significant negative correlation in the main dataset. As Østmarka was the only study location where the CC-site had more deadwood than the NN-site and given that the arthropod biomass was still higher in the NN-site, this result makes sense. It is then possible that Østmarka, having the opposite deadwood volume pattern between the NN- and CC-sites influenced the model for the main dataset causing the slight negative correlation of deadwood volume with arthropod biomass. Deadwood volume also correlated negatively specifically with Diptera biomass and abundance. As discussed, I think this provides further evidence that there has been a community shift with an increase in generalist dipteran species.

Some studies have suggested that deadwood volume should not be used, at least in models that predict saproxylic diversity, and if used at all it should only be in combination with deadwood diversity (Brin et al., 2009; Lassauce et al., 2011). Still, deadwood volume did improve the models that explained arthropod biomass and abundance and deadwood volume is widely recognized to be an important issue for biodiversity conservation in forest ecosystems (Brin et al., 2011; Lassauce et al., 2011; Oettel et al., 2020). Storaunet et al. (2005) found clear evidence of decreasing amount of deadwood with increased logging intensity, and Seibold et al. (2019) found that sites with higher deadwood volume had lower arthropod abundance decline rates in their study between 2008 and 2017 in German forests.

Deadwood diversity was not a significant predictor for either arthropod biomass or abundance in

either forest management type in my study, but the deadwood diversity was consistently higher in the NN-forests. Deadwood diversity is strongly driven by forest management, stand age (diameter at breast height), tree mortality, tree species and forest management practice (Oettel et al., 2020). Deadwood diversity has previously been linked with species diversity as different decay stages and tree species provide more habitat heterogeneity (Siitonen, 1994; Siitonen, 2001). Although I was not able to see a clear effect of deadwood diversity on in our data it does not necessarily mean that it wasn't there.

4.2 Trap type comparisons and beetle capture rates

Different trap types have different beetle capture rates, as is expected (Allison & Redak, 2017; Bouget et al., 2008; Burner et al., 2020). Result show that the single pane IBL-2 traps caught significantly more beetles than the cross-pane and malaise traps (Fig.7). A similar study by Burner et al. (2021) compared beetle species and total abundance using the same traps as in this study. They also found that the IBL-2 trap caught significantly more beetles than the cross-pane window traps and malaise traps, and of the total 558 detected species in the study the Polish IBL traps caught 442 species and the cross-pane traps caught less than 200 species (Burner et al., 2021). Bouget et al. (2008) also compared beetle capture rates of single pane window trap (similar to the Polish IBL-2 traps) with cross-pane traps and found that 88% of beetle species were caught by the single pane traps and cross-pane traps caught only 46%. My results reveal an even larger difference between the traps, although they are measured in abundance and not number of species) than Burner et. al (2021) and Bouget et al.(2008) found, with the average IBL-2 trap in my study catching 152% and 170% more beetles compared to the two cross-pane window traps (no module and with water module respectively), and 55% more beetles that then malaise trap (Fig. 2). One theory why single pane window traps are more effective is the increased surface area, the single pane window trap in my study had almost 2.5 times more surface area than the cross-pane window traps (3950 cm^2 compared to 1600 cm^2). The sample size for malaise traps was considerably lower (n=35) compared to the other window traps (n=96), but the difference in capture rate was still great enough to be significant. Results and literature agree that single pane window traps with larger surface area are far superior to cross-pane traps in terms of beetle capturing (Bouget et al., 2008; Burner et al., 2021).

Although the traps were active for five week and two days, the sampling bottles did not overflow with rainwater. This indicates that trap emptying frequencies up to five weeks work perfectly fine in low precipitation areas/time periods (unless DNA identification is intended), which can reduce the workload and financial burdens of insect monitoring studies. More water was present in window traps without the rainwater diversion module, but this did not seem to affect the beetle capture rates in my study. Burner et al. (2020) also looked at the effects of including a water diversion model in the trap design. They used IBL-2 traps and compared beetle capture rates and species diversity between a standard version and a version including the rainwater diversion module and found that in low precipitation levels the standard version performed better, but with higher precipitation levels the capture rate was higher for traps with water modules. My trapping period was quite dry, and I found no such difference. However, an insect monitoring study by Åstrom et al. (2020) found that window traps in their study flooded regularly and beetles were flushed out. So in areas or time periods with heavy rain, rainwater modules should be added to window traps, even though some beetles may escape the bottom collector in dryer periods (Åström et al., 2020; Burner et al., 2020).

Other trap modifications have been tried in order to target a wide range of arthropods with the same trap (Knuff et al., 2019). Knuff et al. (2019) suggested adding a top collector to the cross-pane window traps to catch insects who tend to orient upwards after colliding with objects such as Dipterans and Hymenopterans. They collected insects in Germany over 5 months and found the top collector to be highly effective, catching 54% of the 230 162 specimens found (Knuff et al., 2019). The bottom collector caught the most beetles (40 095), but the top collector still caught 14 158 beetles. Burner et al. (2021) also included top collectors on their cross-pane traps in a beetle survey in Norway, but they found that the top collectors caught some Dipterans but almost no beetles. Still, adding top collectors to window traps could be a good way to catch a wider range of taxon using only one trap type.

4.3 Lessons for arthropod sampling and monitoring in forests

Less intensely managed forests typically have more deadwood, habitat heterogeneity and host different species groups that those of previously clear-cut forests (Storaunet et al., 2005). My results show that the arthropod biomass is higher in mature near-natural forests and abundance is slightly higher compared to mature clear-cut forests. This increase in biomass is likely partially due to an increase in saproxylic arthropods. It is well known that saproxylic arthropods are threatened because of forest management (Henriksen & Hilmo, 2015; Ulyshen et al., 2018). If left unmanaged, these near-natural forests could function as sources and continue to support the saproxylic population that require continuity of deadwood and the heterogeneity this type of forest provides. My study also shows that near-natural forests are not only important for the conservation of strict saproxylics, but also for a variety of taxa that also benefits presence of dead wood as well as more multi-layered heterogeneity such as springtails, moths and butterflies (Raymond-Léonard et al., 2020; Thorn et al., 2015).

But mature near-natural forests are not protected and constantly under threat of clear-cutting (Felton et al., 2020; Jacobsen et al., 2020). One of the main causes for decline of saproxylic species is lack of continuity in deadwood and deadwood diversity, so simply lowering the intensity of management will not help necessarily help. Finding suitable mature near-natural forests to protect and reducing clear-cutting is more pressing. Monitoring studies of forest arthropods will give more information on vulnerable species, provide decision makers with accurate information on the current state of the population and help find suitable near-natural forests to protect.

As shown in my results, trap types used in arthropod monitoring studies differ significantly in capture rate and specific traps target specific taxa. My results revealed a large difference in the efficiency of different window traps on beetle capture rates. The study by Burner et al. (2021) revealed that beetle species accumulation curved differed between trap types, and had one trap type been excluded they would have estimated a different total number of species present. Another insect monitoring study by Åstrøm et al. (2020) found there to be a significant

difference in capture rate of two different malaise trap types Bugdorm and Watkins, both in abundance and biomass with the Watkins trap catching significantly more. This stresses that a variety of methods and traps are needed to capture arthropods effectively, and the same methods and trap types should be used consistently throughout the experiment. Caution should be exercised when making conservation decisions based on comparison of abundance and species richness among forest managements, if sampling methods and trap types vary (Burner et al., 2021).

5. Conclusion

Lower biomass and abundances were found in mature clear-cuts compared to mature near-natural stands. What caused the lower biomass and abundances in mature clear-cut stands remains unclear, it is likely driven by mechanisms that negatively affect the abundances of many species, which leads to an overall decline in biomass. Forest management did not affect each arthropod order the same way, while most orders showed higher abundances in near-natural forests, Diptera the most abundant order I sampled showed the opposite trend. This could suggest a community shift in Diptera in previously clear-cut sites with fewer saproxylic individuals and dominance of more generalist species. Lepidoptera and Collembola, which are generally not saproxylic dominated groups, were more abundant in near-natural forests. This highlights that near-natural forest hold other important habitat qualities such as habitat heterogeneity and multi-layered canopies including an herbaceous shrub-layer.

It is difficult to compare arthropod capture data between studies due to difference in sampling methods. Trap types differ in catch rates and despite efforts to find a “one catches all” trap or modifying traps to broaden the taxonomic range it seems clear that certain traps are superior for certain groups of taxa. IBL-2 window traps are superior at catching beetles, and malaise tents are superior at catching Diptera and Hymenoptera. When aiming at sampling a broad range of taxa, complementary trapping methods should be used, and the same traps should be used throughout the project.

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APPENDIX 1. Coordinates for each trap-group placement in each site.

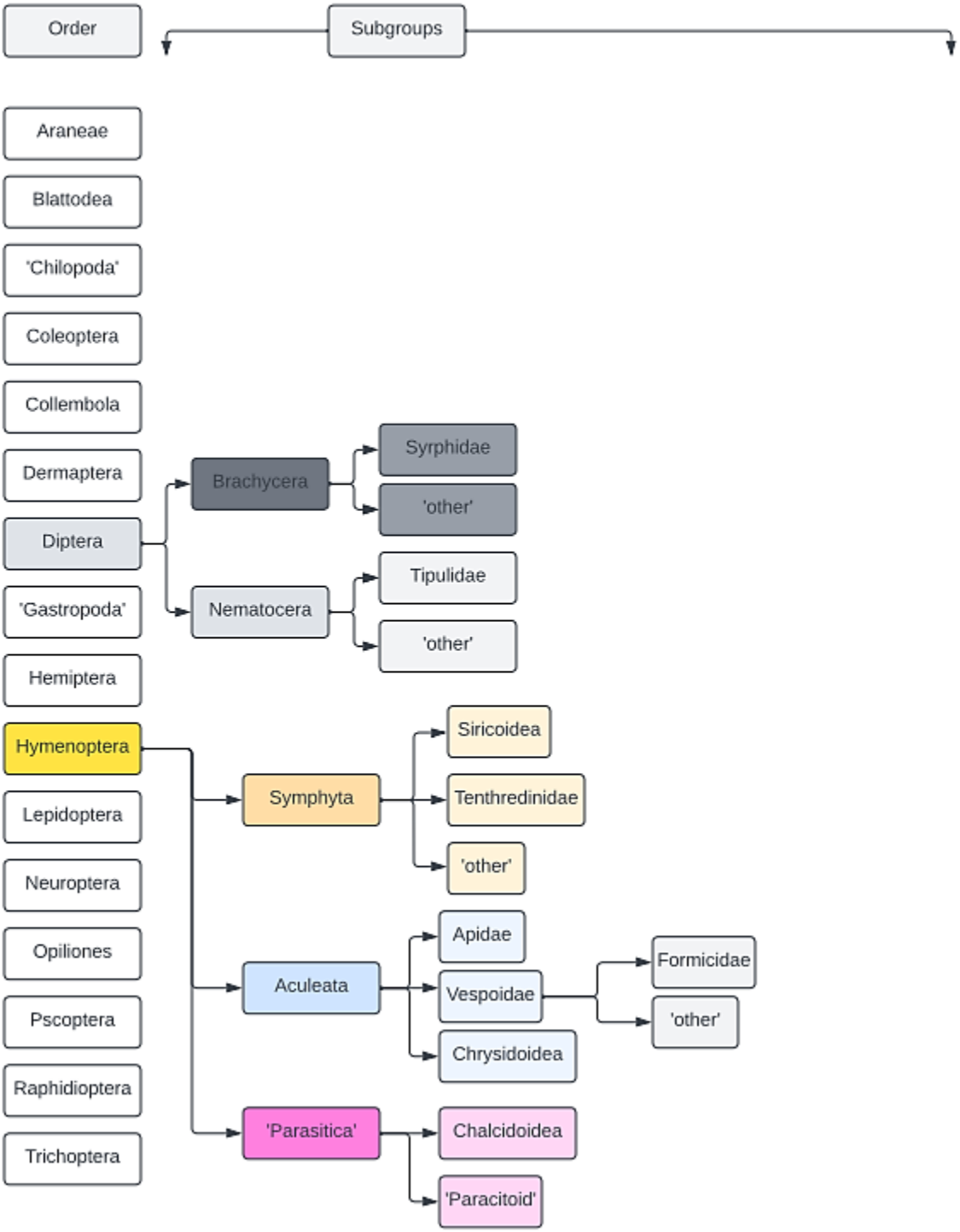
Latitude	Longitude	Name
60.920867007225752	12.188708027824759	Gravberget C-G1
60.920903971418738	12.189483018592	Gravberget C-G2
60.920616975054145	12.188135040923953	Gravberget C-G3
60.921161966398358	12.188148032873869	Gravberget C-G4
60.915249958634377	12.2066929936409	Gravberget N-G1
60.915306033566594	12.206011964008212	Gravberget N-G2
60.915678022429347	12.205993020907044	Gravberget N-G3
60.914829019457102	12.207146035507321	Gravberget N-G4
60.23080101236701	10.762494010850787	Lunn C-G1
60.230838982388377	10.76323295943439	Lunn C-G2
60.230505969375372	10.763210998848081	Lunn C-G3
60.230718031525612	10.764095038175583	Lunn C-G4
60.235370993614197	10.775284040719271	Lunn N-G1
60.235061030834913	10.774668976664543	Lunn N-G2
60.235724039375782	10.774487005546689	Lunn N-G3
60.235779024660587	10.775211034342647	Lunn N-G4
59.854167988523841	11.026859991252422	OST N - G2
59.85480803065002	11.026761000975966	OST N- G1
59.854535032063723	11.027315966784954	OST N- G3
59.854887994006276	11.027470026165247	OST N- G4
60.740155018866062	11.92626996897161	Val N-G1
60.739802978932858	11.926655033603311	Val N-G2
60.740060973912477	11.926952004432678	Val N-G3
60.740458024665713	11.92678302526474	Val N-G4
60.200301026925445	12.528118025511503	Var C-G1
60.200304966419935	12.527022007852793	Var C-G2
60.200412003323436	12.527601029723883	Var C-G3
60.199955021962523	12.528050970286131	Var C-G4
60.187967978417873	12.507943036034703	Varald N-G1
60.18802497535944	12.506982972845435	Varald N-G2
60.188141986727715	12.50725002028048	Varald N-G3
60.188109967857599	12.507613962516189	Varald N-G4
60.747482981532812	11.927160965278745	Val C-G1
60.747294975444674	11.926627960056067	Val C-G2
60.747825969010592	11.927640996873379	Vål C-G3
60.747105041518807	11.92768600769341	Vål C-G4
59.854167988523841	11.026859991252422	OST N - G2
59.85480803065002	11.026761000975966	OST N- G1
59.854535032063723	11.027315966784954	OST N- G3
59.854887994006276	11.027470026165247	OST N- G4
59.861897025257349	10.998977003619075	OST-C-G1
59.861765010282397	10.999380005523562	OST-C-G2
59.861205015331507	10.998862003907561	OST-C-G3
59.861673982813954	10.999068031087518	OST-C-G4

APPENDIX 2. Schedule for activating and emptying traps.

Schedule 2021	June		July			Aug					Sept
	Week 25	Week 26	Week 27	Week 28	Week 29	Week 30	Week 31	Week 32	Week 33	Week 34	Week 35
Tasks											
Prepare											
Put up traps											
Activate traps											
Active trap											
Collect traps											
Deliver to freezer											

Ostmarka
All 5 sites

APPENDIX 3. Complete list of orders and taxonomic subgroups used for sorting malaise traps.



APPENDIX 4 Summarized biomass and abundance caught per malaise trap (n=29) placed in clear-cut site (CC) or near-natural site (NN). One trap was missing in the NN-site at Lunner.

Malaise trap		Biomass (g/wet)		Abundance	
		CC	**NN**	**CC**	**NN**
GRAV	1	5.00	11.67	514	665
GRAV	2	13.53	7.86	1167	813
GRAV	3	10.20	8.03	827	699
LUNN	1	11.73	13.14	874	1370
LUNN	2	8.06	8.66	1068	840
LUNN	3	8.78	-	1065	-
OST	1	2.26	8.17	611	825
OST	2	4.43	4.34	790	583
OST	3	3.36	5.99	728	1101
VAL	1	4.41	2.76	566	369
VAL	2	2.15	3.82	451	873
VAL	3	6.33	1.77	1316	242
VAR	1	1.85	13.54	229	788
VAR	2	2.25	6.38	362	804
VAR	3	5.34	11.10	525	1464
Average		5.98	7.66	739.53	816.86
Difference		1.68 g 28.12 %		77.32 g 10.46 %	

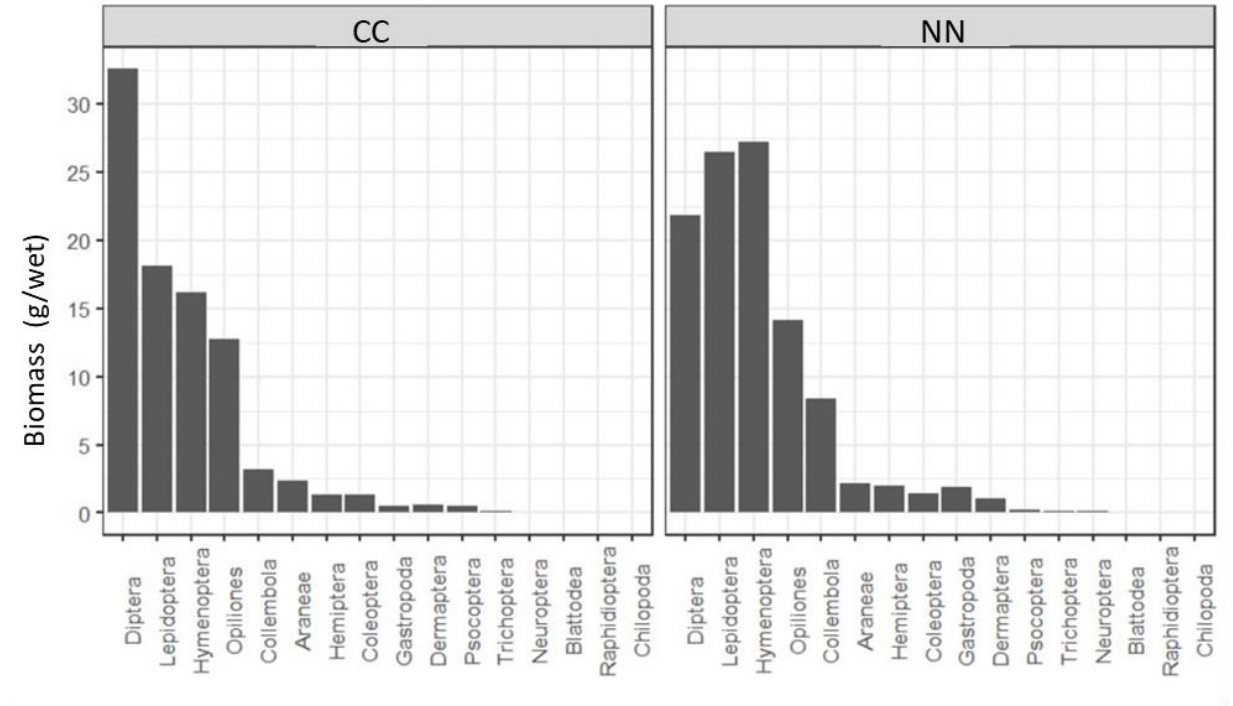
APPENDIX 5 Summarized biomass and abundance per arthropod order in clear-cut site (CC) and near-natural site (NN). Lack of data on specific orders are indicated by - , and significant difference between CC- and NN- value is indicated with *.

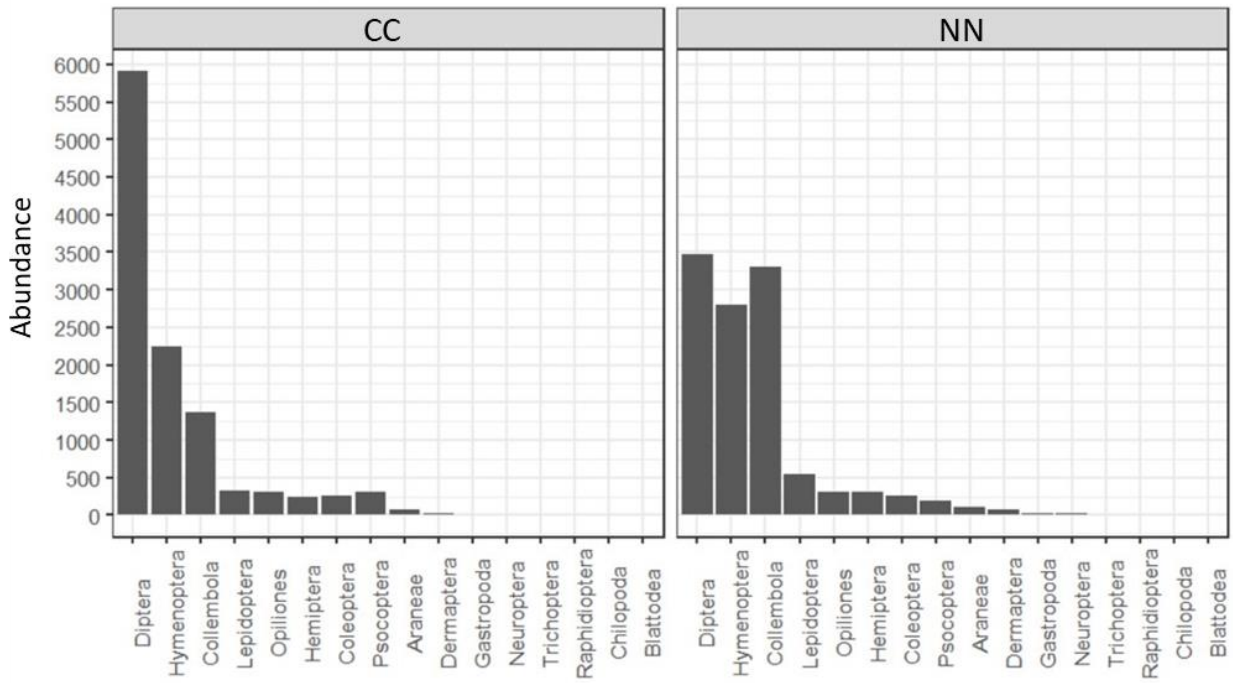
	Biomass (g/wet)					Abundance				
Order	**CC**	**NN**	**CC-NN**	**% Diff**	**p**	**CC**	**NN**	**CC-NN**	**% Diff**	**p**
Araneae	2.64	2.93	-0.29	9.98	*	100	129	-29	22.48	*
Blattodea	-	0.05	-	-	-	-	1	-	-	-
Chilopoda	0.02	0.08	-	-	-	1	3	-	-	-
Coleoptera	3.83	4.98	-1.15	23.02		434	466	-32	6.87	
Collembola	8.57	13.79	-5.22	37.83	*	3678	5375	-1697	31.57	*
Dermaptera	0.77	1.12	-0.35	31.51		31	87	-56	64.37	
Diptera	42.78	40.40	2.38	5.89	*	6991	4275	2716	63.53	*
Gastropoda	0.53	2.07	-1.53	74.18	*	11	31	-20	64.52	
Hemiptera	1.73	2.36	-0.63	26.59		306	350	-44	12.57	
Hymenoptera	22.07	36.61	-14.54	39.71		2888	3670	-782	21.31	*
Lepidoptera	25.86	36.55	-10.70	29.26	**	542	859	-317	36.90	**
Mecoptera	0.09	0.05	-	-	-	2	1	-	-	-
Neuroptera	0.05	0.12	-0.07	58.59		6	26	-20	76.92	
Opiliones	15.39	17.98	-2.58	14.38		377	394	-17	4.31	
Psocoptera	0.53	0.45	0.07	16.42		345	322	23	7.14	
Raphidioptera	-	0.02	-	-	-	-	3	-	-	-
Trichoptera	0.36	0.29	0.07	23.48		7	8	-1	12.50	*

APPENDIX 6 Summarized biomass and abundance per order from malaise traps (n=29)

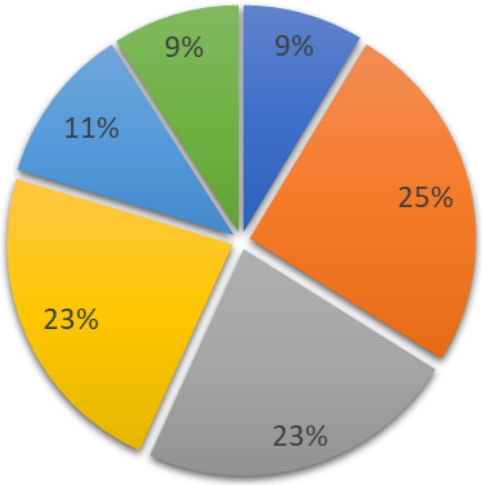
Order	Biomass (g/wet)	Abundance
Araneae	5.5684	229
Blattodea	0.0549	1
Chilopoda	0.0941	4
Coleoptera	8.8131	900
Collembola	22.36045996	9053
Dermaptera	1.8953	118
Diptera	83.18433897	11266
Gastropoda	2.5998	42
Hemiptera	4.084225758	656
Hymenoptera	58.68294589	6558
Lepidoptera	62.41262903	1401
Mecoptera	0.1397	3
Neuroptera	0.1745	32
Opiliones	33.3666	771
Psocoptera	0.977544526	667
Raphidioptera	0.0248	3
Trichoptera	0.6501	15
SUM	285.0834441	31719

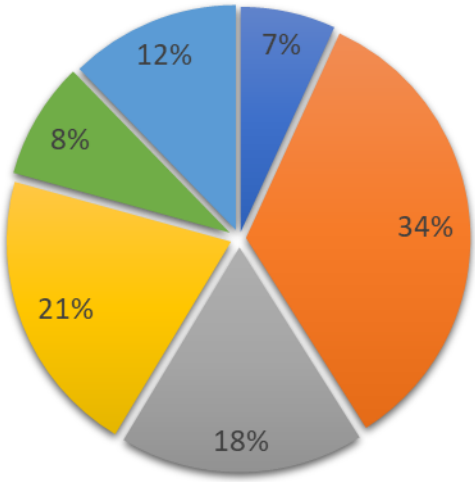
APPENDIX 7 Summarized biomass and abundance per order for all clear-cut (CC) and near-natural (NN) sites.

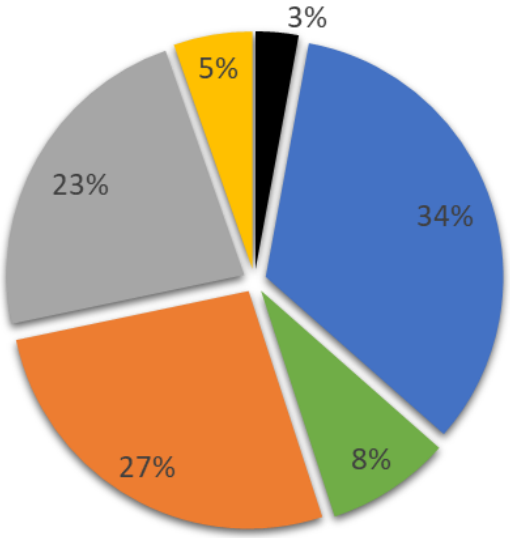


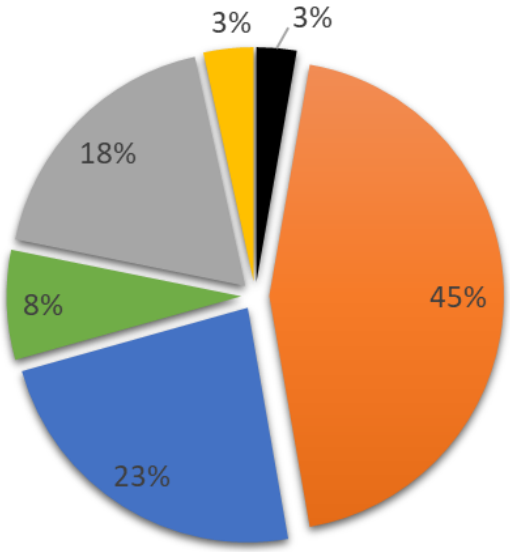


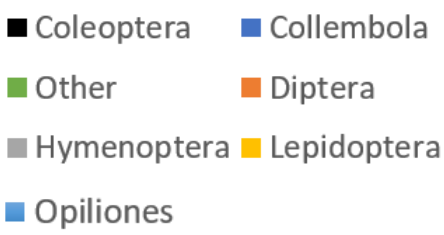
APPENDIX 8 Biomass composition (top) by arthropod order, in near-natural (NN) sites (left) and clear-cut (CC) sites (right). And abundance composition (bottom) by arthropod order, in near-natural (NN) sites (left) and clear-cut (CC) sites (right)

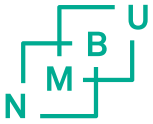












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