THE ACTIVITY OF ARCTIC ANTHROPODS IN A CHANGING CLIMATE

Summer abundance in 2008-2018 and relations to environmental changes

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Research project

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Abstract

The Arctic region experiences global warming at a much faster pace than the rest of the globe, showing a temperature increase of 0.75°C over the past decade alone. Affected by the implications of climate change are a key ecological group: Arctic arthropods, who are vital to the dynamics of the Arctic food web and ecological functioning. Samples from pitfall traps, collected on Svalbard during the years 2008-2018 were used to form a large dataset, and the effect of annual values of temperature and precipitation on the average abundance of Arctic arthropods was studied. The biggest impacts of temperature, as well as precipitation, were seen in the springtail family Hypogastruridae. During the studied years, the abundance of Chironomidae, Sciaridae, and Araneae seem to be repressed by rising temperatures and more precipitation, while the abundance of Mycetophilidae seems to increase. For 6/10 groups, an in-depth comparison between two years that differed in mean temperature and precipitation showed alternative results than when looking at the trend of these groups in the ten-year dataset, indicating a wide range of intra- and inter-season variability affected by day-to-day weather changes.

Introduction

The threat climate change poses to biodiversity and ecosystem services has been well-documented over the past decades. The consequences of climate change in the years to come will be determined by the response of the Earth's natural forces as well as human intervention in the field of technology, policy, economy, and lifestyle (Moss et al. 2010). The Arctic region experiences global warming at a much faster pace than the rest of the globe, showing a temperature increase of 0.75°C over the past decade alone and thus greatly exceeding the global average (Post et al. 2019). The expected general implications include ongoing loss of land and sea ice, weather changes at lower latitudes leading to extreme conditions, increased methane emission, and serious consequences for wildlife and (local) human sustenance (Post et al. 2019). As a result of having a unique seasonal cycle that is strongly affected by temperature related effects such as permafrost, snow cover and glacier run-off, the impact of a continuous rise in temperature is larger in the Arctic region (Corell 2006). This is most noticeable during the summer season when active surface layers become larger and withstand the cold of the following season longer (Harris et al. 2009), the melt season is longer and vegetation thrives, leading to increased productivity (Serreze & Francis 2006, Sturm et al. 2001). Naturally, this affects the distribution and survival of native, migrating, and newly emerging species (Parmesan & Yohe 2003, Coulson 2015, Alsos et al. 2015).

Well-adjusted to the seasonal fluctuations in the High Arctic, with short summers and long, cold winters, arthropods excel in species richness and abundance. Present year-round, they are a key ecological group that act as grazers, decomposers, pollinators, prey, and predator, making them vital to the dynamics of the Arctic food web and ecological functioning (Gillespie et al. 2020, Jorna 2016). Being ectothermic, arthropods are highly sensitive to environmental changes since the regulation of their physiological functions are dependent on environmental temperatures (González-Tokman et al. 2020). This means that the predicted climatic changes in their habitat can also play a determining role as for their phenology: exposing Arctic arthropods to conditions to which they are not adapted (Høye & Forchhammer 2008). Given that climate change has the biggest impact on polar regions, expressed in a rise in air temperatures above the Arctic Circle twice the global average (American Institute of Physics 2017), and the fact that general species diversity is lower in tundra regions compared to warmer regions, the knowledge gaps about arthropod life here are particularly problematic (Høye & Culler 2018). Results drawn from a previous long-term (1996-2014) arthropod dataset from Zackenberg, Greenland suggest ongoing changes in the Arctic due to climate change, affecting species interactions and food web dynamics, influencing key ecosystem processes (Koltz et al. 2018).

In the past years, the examination of the effects of climate change in polar regions on arthropod life has received more attention. For instance, previous research in Greenland considers the date of snowmelt to be significantly related with insect abundance (Høye & Forchhammer 2008) and another research project suggests mosquitoes grow faster and avoid increased mortality from predators due to temperature increases (Culler et al. 2015). Nevertheless, the number of publications of Arctic studies on insects is declining and innovative research is desired (Høye 2020).

This report is based on an ongoing large-scale research, dedicated to monitoring the course of insect abundance on Svalbard over the past recent years. Since this study is the first long-term analysis of the relative abundance of arthropods on Svalbard (Biersma et al. n.d.), it will be a valuable resource for changes in the Arctic for future references. The aim of this research project is to improve understanding and/or gain additional knowledge of the activity of Arctic arthropods in changing weather conditions. Therefore, the research question that will be discussed in this report is: 'What is the effect of annual values of temperature and precipitation on average abundance of Arctic arthropods?' With background knowledge retrieved from literature search on arthropod composition regarding weather conditions and the previous studies from Elise Biersma et al. (n.d.) and Jesse Jorna (2016) on the same (less complete) dataset, the expectation is to see a wide range of intra- and inter-seasonal variability between the years but an overall increasing abundance of arthropods that can be assigned to a warming Arctic.

Materials & Method

Study area and data

The large-scale study that this report is based on has been conducted for several years now on the tundra near Ny-Ålesund, Svalbard (78,9'° N; 11,9'° E) during the summer months, which is the active season for most arctic arthropods (Jorna 2016). During these years (2008-2020) the mean summer temperature was 4.6°C (OpenClimateDataPrototype n.d.).

Since 2008, insects were collected every year during the months of June, July and August using 5 pitfall traps on humid terrain, with a retrieval interval of 2-4 days. The pitfall traps used to capture surface active, sub-surface active and low-flying arthropods were similar to the ones described in Gauthier and Berteaux's report (Gauthier & Berteaux 2011), but were adjusted after the first years, resulting in the trap seen in figure 1 (left). The traps consisted of an elongated low tray with a soap solution in water. A 15cm high netting over the basket made sure that low flying insects were also captured in the trap. This method of trapping measures a combination of arthropod abundance and surface activity (not absolute abundance of arthropods), which is sufficient for the determination of season and weather-induced variation in arthropod prosperity (Tulp & Schekkerman 2008). The captured insects were then stored in tubes containing ethanol, registered with ascending numbers to indicate the order of capture throughout the summer, trap number, date and time of placement of the trap, and date and time of emptying of the trap (fig. 1, right).

FIG. 1. Pitfall trap used to capture arthropod: a tray with soapy water topped with a net (left). The storage of catches per trap: filtered through a coffee filter and then transferred into 15ml tubes with Ethanol (right). (Vliegende Instecten 2020).

Using a binocular (magnification: x1,6-x4,5 depending on the insect), the collected samples were analysed, determining insect quantity, and identifying insect diversity, preferably at family level or otherwise at lowest taxonomic level possible. The data that had already been analysed in this collection resulted in the categories presented in table 1. A couple of handmade drawings of the insects are found in the Appendices (supplementary fig. 1).

TABLE 1. Categories arthropods acknowledged in this project, presented with their formal name, common name and taxonomic classification.

Formal name	**Common name**	**Taxonomic classification**
Chironomidae	Nonbiting midges	Family (Order: Diptera)
Sciaridae	Dark-winged fungus gnats	Family (Order: Diptera)
Mycetophilidae	Fungus gnats	Family (Order: Diptera)
Brachycera	Short-horned flies	Suborder (Order: Diptera)
Hypogastruridae	Springtails	Family (Subclass: Collembola)
Isotomidae	Elongate-bodied springtails	Family (Subclass: Collembola)
Sminthuridae	Globular springtails	Family (Subclass: Collembola)
Ichneumonidae	Ichneumon wasps	Family (Order: Hymenoptera)
Symphyta	Sawflies	Suborder (Order: Hymenoptera)
Araneae	Spiders	Order (Class: Arachnida)
Acari	Mites/Ticks	Subclass (Class: Arachnida)

During this research project, the collected samples of 2018 and 2015 were analysed and documented. In the end of the project, the complete dataset consisted of the following years of analysed samples: 2008, 2009, 2010, 2012, 2013 (E. Biersma), 2014 (J. Jorna), 2015 (V. Neijboer), 2016 (J. Jorna), and 2018 (V. Neijboer). This is the dataset that was used to look for changes in diversity and activity during the summer seasons. To define a corresponding length of the summer season for all documented years, the period of start until end is consecutively the 29th of June until the 8th of august.

Weather

As can be seen in the figure below, the temperature in Ny-Ålesund is increasing each year. The summers of 2008, 2009, 2010, and 2014 were relatively cold, and the summers of 2011 and 2015 were relatively warm. The other years followed the trend of increasing temperature over the study period.

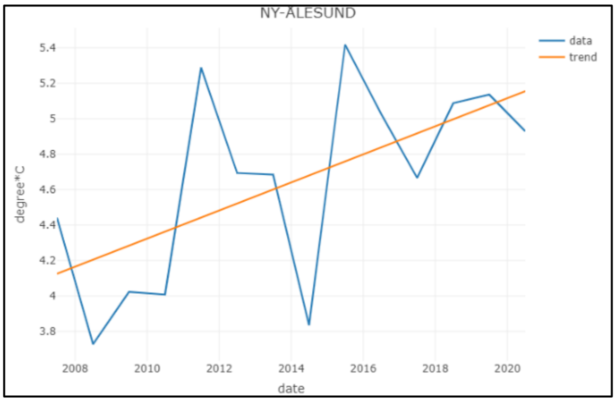

FIG. 2. The temperature trend of the past 12 years in Ny-Ålesund. The data points are averages over the summer months (Jun-Aug) of the corresponding year, resulting in 'delayed' points with respect to the x-axis. The mean temperature was 4.6°C and there is a trend of 0.79 degree per decade (OpenClimateDataPrototype n.d.).

The following figure shows the mean precipitation in Ny-Ålesund for the years involved in the project. As can be indicated from the figure, the summers of 2008 and 2010 were relatively dry, and the summers of 2013 and 2018 were relatively wet.

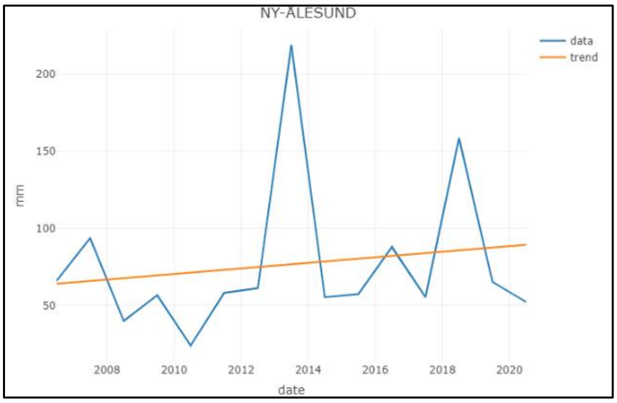

FIG. 3. The precipitation trend of the past 12 years in Ny-Ålesund. The data points are averages over the summer months (Jun-Aug) of the corresponding year, resulting in 'delayed' points with respect to the x-axis . The mean precipitation was 79.6mm and there is a trend of 18.07mm per decade (OpenClimateDataPrototype n.d.).

Figures 2 and 3 reveal the summers of 2008 and 2010 to be cold and dry, and the summer of 2015 to be warm and dry. In the Appendices, an extra table and figure are placed to provide an overview of the combination between temperature and precipitation for the analysed years (supplementary table 1 and supplementary fig. 2)

Statistical analyses

Due to the timeframe of the project and the lack of experience of the student performing statistical analyses, it has been decided to omit the statistical analyses. It is highly recommended to perform the necessary statistical analyses anyway at a later date.

Analysis

Pitfall traps

Figure 4 shows the abundance of all studied species, during the two years that were analysed during this project (2015; 2018), summed between all five individual traps. Similar charts of the previously analysed years of pitfall trap catches can be found in the Appendices (supplementary fig. 3). Supplementary table 2 in the Appendices shows an overview of the interpreted course of the insects per group per year (displayed as either ascending, descending, peaked or unknown). Across the entire data set, it is striking that (almost) all years the population of springtails (Sminthuridae and Hypogastruridae) dominate.

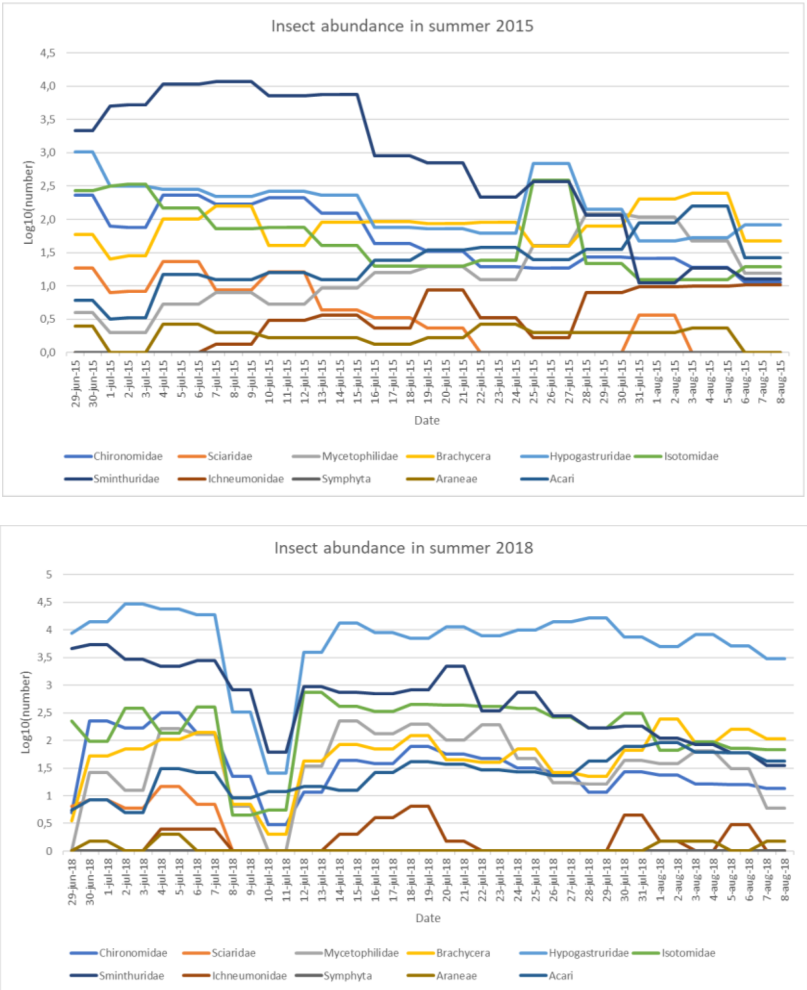

FIG. 4. Abundance of Arctic Arthropods in the summer season in Ny-Ålesund. The y-axis indicates the number of caught individuals per species group in logarithm. The x-axis shows the same range of dates in all studied years (interval is calculated to1 day; start date is June 29 or the next day with data; the end date is August 8).

When looking at the graph of 2018, the dip that all insects show around the interval of 9-11 July immediately stands out. Weather data has been consulted and shows an average temperature of 5,9 °C, precipitation of 17,6 mm and wind speed of 4,0 m/s during this interval (Meteorologisk Institutt et al. n.d.). Studying the interval of 1 July – 19 July, the precipitation on these 3 days was quite high (supplementary fig. 4).

Chironomidae (Nonbiting midges) - For all the years except 2014, a cold year, the population of Chironomidae is largest at the beginning of the season and decreases slowly until reaching to a minimum in august. It is also striking that their numbers in the years 2010 and 2012 were a lot lower throughout the season in comparison with the other years. 2018 was a year with large differences in catches during the season.

Sciaridae (Dark-winged fungus gnats) - Insects of the Sciaridae family were hardly or no longer found in the catches from mid-July in the years 2010, 2012, 2016, and 2018. In 2014, a cold year, the catch of Sciaridae remained reasonably high compared to other years, and it was the only year that Sciaridae were also caught in the samples from August. Compared to the other years, there were many Sciaridae in the month of July of 2008, another cold year. This suggests a slower development and later emergence of this group in cold years.

Mycetophilidae (Fungus gnats) - In 2010, the coldest year, the population Mycetophilidae was low in comparison with the other years. In 2012 and 2015, the population Mycetophilidae was growing in July up to and including the beginning of August. There were three very clear drops in the number of Mycetophilidae that were caught in 2014. The highest peak in numbers of Mycetophilidae was reached in 2016 (mid-July). In most years, the population peaked in mid-July, in 2015 not until the beginning of August.

Brachycera (Short-horned flies) **-** In almost all years, the number of Brachycera increases during the season. In 2012 and 2015, the number of Brachycera during the season remains fairly stable compared to the other years. The highest peak in numbers of Brachycera was reached in 2016 (early July).

Hypogastruridae (Springtails) - In all years, the number of Hypogastruridae decreases during the season. In the years 2008, 2012, 2014, and 2018, the population Hypogastruridae starts very high compared to the other years. The number of Hypogastruridae during the season was highest in 2018, with a remarkably low catch on 10/11 July. In 2015, there was a remarkably high catch on 25/26 July compared to the rest of this year. In 2009 and 2010 there were a lot of fluctuations in the catch of Hypogastruridae in comparison to the other years.

Isotomidae (Elongate-bodied springtails) **-** In almost all years, the population Isotomidae decreases during the season. The catch of Isotomidae was lowest in 2010, with many fluctuations during the season. The latter also applies to the year 2012. The amount of Isotomidae in the pitfall traps remains fairly stable in 2013. In the years 2008, 2009, 2014 2015, and 2016, the amount of Isotomidae shows a reasonable linear decrease, with an occasional outlier. Notable outliers are seen in 2015 (Jul 25: high), 2016 (Jul 31: low, Aug 8: high), and 2018 (Jul 8-11: low).

Sminthuridae (Globular springtails) **–** Again, in almost all years the number of Sminthuridae (slowly) decreases during the season. The population of Sminthuridae at the beginning of the season is the highest in 2015, in comparison with the other years. At the end of the season, the population is the highest in 2014, a cold year suggesting late emergence. In 2010, 2012, and 2016, the population of Sminthuridae decreased most during the season (with one peak in 2010 around Aug 2). In 2014, the population is fairly stable during the season.

Ichneumonidae (Ichneumon wasps) **-** In the years 2008, 2012, 2013, and 2014, there were no Ichneumonidae caught in the beginning of the season. In the years 2012 and 2014, the fewest Ichneumonidae were caught (or registered) at a given time compared to the other years. Relatively many Ichneumonidae were caught in 2015, the warmest year, but there was no distinction made during the analysis between Ichneumonidae and Symphyta.

Symphyta (Sawflies) **-** Members of the Symphyta family were hardly registered during this study. In 2008 (1), 2009 (0), 2010 (2), 2012 (1), 2013 (0), 2014 (x), 2015 (0), 2016 (x) & 2018 (5, but not sure). Therefore, this family was not considered for the remaining analysis of the project.

Araneae (Spiders) **-** In 2013, 2015, 2016, and 2018, very few Araneae were caught during the season. In 2009 there were a lot of Araneae caught in the pitfall traps during the season, with a lot of variation between dates.

Acari (Mites/Ticks) **-** For all years, the number of Acari increased during the season. In 2008, the coldest year, the first registration of Acari was on July 15 (relatively late in comparison with the other years). In 2015, the population Acari appeared to be growing fairly linearly during the season. The highest peak of the number of Acari in one catch was in 2009. In 2014, the second coldest year, the number of Acari caught per interval during the season was lowest.

Species differences with regard to temperature

To investigate the effect of temperature on Arthropod abundance, the data of 2014 (relatively cold year with a mean temperature of 5,3°C in July) and 2015 (relatively warm year with a mean temperature of 6,6°C in July) were compared in table 3 and fig. 5. For this purpose, the mean number of insects per day per group in a year was calculated (table 2). The same table with the values in logarithms can be found in the Appendices (supplementary table 3).

It can be derived from figure 5 that temperature seemed to influence the abundance of Sminthuridae, Acari, Mycetophilidae, and Ichneumonidae, preferring a higher temperature. During a cold summer, Sciaridae, Chironomidae, Isotomidae, and especially Hypogastruridae seemed to thrive. The effect of temperature on arthropod abundance in general does not seem to be very strong, since all data points are reasonably close to the y=x line.

TABLE 2. The mean number of insects per group per day during the summer season of the analysed years (2008-2018) in absolute numbers. The summer season is defined by the 29th of June until the 8th of August.

Species / Year	Chironomidae	Sciaridae	Mycetophilidae	Brachycera	Hypogastruridae	Isotomidae	Sminthuridae	Ichneumonidae	Araneae	Acari
2008	138	33	17	26	1282	35	968	2	5	51
2009	119	39	54	34	107	37	1009	7	11	58
2010	52	7	5	56	168	9	471	4	7	60
2012	37	9	50	77	1426	102	563	1	5	28
2013	128	9	70	88	543	132	394	2	3	17
2014	200	14	12	133	1810	282	1021	1	3	11
2015	85	6	30	98	236	100	3395	5	2	36
2016	83	2	141	158	128	66	868	3	1	65
2018	64	2	72	77	10337	260	1161	2	1	33
Mean	101	14	50	83	1782	114	1094	3	4	40
Standard deviation	51	14	42	43	3272	97	904	2	3	20

TABLE 3. Arthropod abundance regarding the difference in temperature. The mean number of insects per group per day during the summer season of 2014 (mean temperature of 5,3°C in July) and 2015 (mean temperature of 6,6°C in July) shown in logarithm. The summer season is defined by the 29th of June until the 8th of August. Also, the percentage of change of arthropod abundance in 2015 relative to 2014 is presented. The table is sorted by arthropod size in 2014 to make the corresponding chart easier to read.

	2014	2015	%
Ichneumonidae	0,041	0,663	1617,073
Araneae	0,491	0,255	51,935
Acari	1,029	1,558	151,409
Mycetophilidae	1,064	1,477	138,816
Sciaridae	1,158	0,792	68,394
Brachycera	2,122	1,992	93,874
Chironomidae	2,302	1,929	83,797
Isotomidae	2,450	2,001	81,673
Sminthuridae	3,009	3,531	117,348
Hypogastruridae	3,258	2,373	72,836

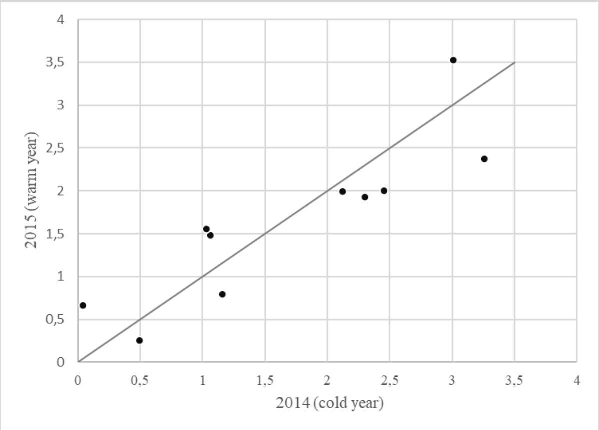

FIG. 5. Comparison of arthropod abundance in 2014 and 2015 in logarithm regarding the difference in temperature (2014 = cold, 2015 = warm). The points above the x=y line indicate higher numbers in a warm year and the points below the x=y line indicate lower numbers in a warm year.

Since temperature seemed to have the biggest impact on the abundance of the Hypogastruridae population, this family was selected for further investigation. Is there a negative relation between the numbers of Hypogastruridae and temperature? Emergence of the first arthropods is determined by the onset of temperature rise and snowmelt (Tulp & Schekkerman 2008), which happens late May/begin June (Boike et al. 2003). Thus, the mean temperature in Ny-Ålesund in June for all analysed years was plotted against the mean number of Hypogastruridae per day (table 4 and fig. 6).

TABLE 4. The mean temperature in June in Ny-Ålesund in degree Celsius put next to the mean number of Hypogastruridae per day during the summer season for all analysed years (2008-2018) (Meteorologisk Institutt et al. n.d.). The table is sorted by arthropod size to make the corresponding chart easier to read.

Hypogastruridae	Mean temperature (°C) in June	Year
2,028	1,6	2009
2,109	3,8	2016
2,225	2,8	2010
2,373	3,8	2015
2,735	3,2	2013
3,108	2,6	2008
3,154	3,7	2012
3,258	2	2014
4,014	3,4	2018

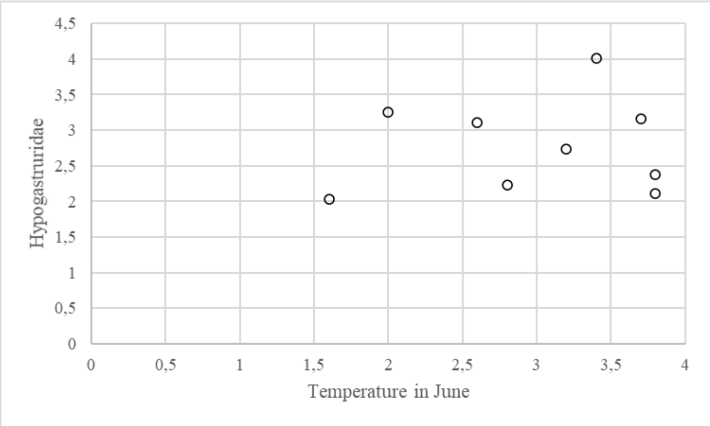

FIG. 6. The relation between temperature in June (in degree Celsius) and the abundance of Hypogastruridae (in logarithm) for the period of 2008-2018. Dots at the top left indicate many Hypogastruridae at low temperatures; dots at the top right indicate many Hypogastruridae at high temperatures; dots at the bottom left indicate few Hypogastruridae at low temperatures; dots at the bottom right indicate few Hypogastruridae at high temperatures.

The figure does not show a convincingly relationship between temperature and Hypogastruridae abundance. While a negative influence of temperature on Hypogastruridae abundance was expected (resulting from fig. 5), a weak increasing trendline can be drawn through the data. However, when 2018 (a particularly wet year) is not considered, there is a weak declining trendline. Could it be that precipitation overshadowed the effect of temperature on arthropod abundance?

Species differences with regard to precipitation

For the effect of precipitation on Arthropod abundance, the data of 2015 (relatively dry year with a mean precipitation of 13,2 mm in July) and 2018 (relatively wet year with a mean precipitation of 99,4 mm in July) were compared in table 5 and fig. 7. Again, the mean number of insects per day per group over a year was used (supplementary table 3).

The graph shows a few points worth mentioning, the most striking point for Hypogastruridae, thriving during the wet summer season of 2018. The numbers for Isotomidae and Mycetophilidae were also higher during the wet season in comparison to the dry season. The population of Sminthuridae, Ichneumonidae, and Sciaridae indicate a higher abundance during the dry summer season of 2015. However, the effect of precipitation on arthropod abundance in general appears, like temperature, not to be very strong.

TABLE 5. The difference in precipitation. The mean number of insects per group per day during the summer season of 2015 (mean precipitation of 13,2 mm in July) and 2018 (mean precipitation of 99,4 mm in July) in logarithm. The summer season is defined by the 29th of June until the 8th of August. Also, the percentage of change of arthropod abundance in 2018 relative to 2015 is presented. The table is sorted by arthropod size in 2015 to make the corresponding chart easier to read.

	2015	2018	%
Araneae	0,255	0,000	0,000
Ichneumonidae	0,663	0,204	30,799
Sciaridae	0,792	0,322	40,664
Mycetophilidae	1,477	1,859	125,862
Acari	1,558	1,521	97,665
Chironomidae	1,929	1,805	93,567
Brachycera	1,992	1,884	94,556
Isotomidae	2,001	2,415	120,679
Hypogastruridae	2,373	4,014	169,136
Sminthuridae	3,531	3,065	86,797

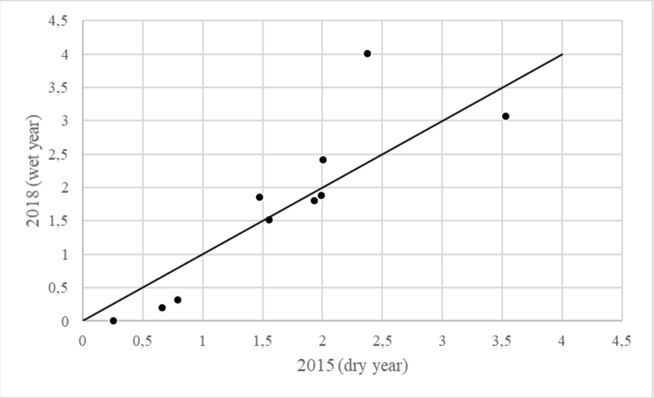

FIG. 7. Comparison of arthropod abundance in 2015 and 2018 regarding the difference in precipitation (2015 = dry, 2018 = wet). The points above the x=y line indicate higher numbers in a wet year and the points below the x=y line indicate lower numbers in a wet year.

Again, the biggest impact seemed to be on the abundance of the Hypogastruridae population, so yet again this family was highlighted. Is there a positive correlation between the numbers of Hypogastruridae and precipitation? The mean precipitation in Ny-Ålesund in June was plotted against the mean number of Hypogastruridae per year (table 6 and fig. 8).

TABLE 6. The mean precipitation in June in Ny-Ålesund in millimetres put next to the mean number of Hypogastruridae per day during the summer season for all analysed years (2008-2018) (Meteorologisk Institutt et al. n.d.). The table is sorted by arthropod size to make the corresponding chart easier to read.

Hypogastruridae	Mean precipitation (mm) in June	Year
2,028	10,6	2009
2,109	6,9	2016
2,225	5	2010
2,373	1,7	2015
2,735	48	2013
3,108	7,6	2008
3,154	24,9	2012
3,258	6,4	2014
4,014	8,6	2018

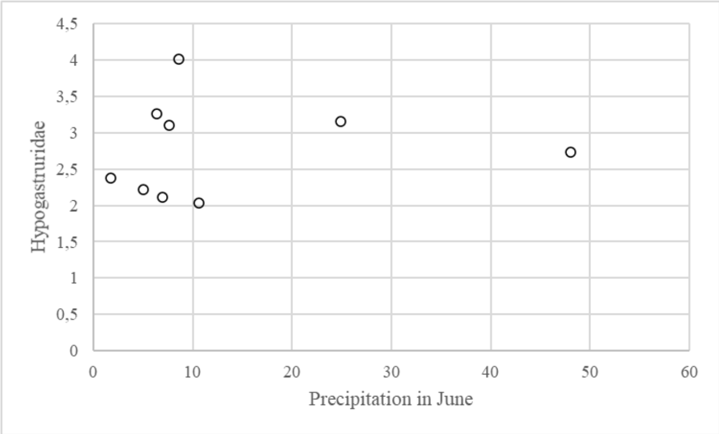

FIG. 8. The relation between precipitation in June (in mm) and the abundance of Hypogastruridae (in logarithm) for the period of 2008-2018. Dots at the top left indicate many Hypogastruridae at low precipitation; dots at the top right indicate many Hypogastruridae at high precipitation; dots at the bottom left indicate few Hypogastruridae at low precipitation; dots at the bottom right indicate few Hypogastruridae at high precipitation.

While a weak increasing trendline can be drawn through the data, the graph does not show a convincing relationship between precipitation and Hypogastruridae abundance.

Multiple regression

A multiple regression of Hypogastruridae abundance against both temperature and precipitation did not show an effect of both factors simultaneously.

Discussion

In this report the effect of annual values of temperature and precipitation on average abundance of Arctic arthropods was studied, using the catches of arthropods from different taxa in pitfalls. Arthropods are highly sensitive to changes in their environment (Høye 2020), making them a suitable candidate for studies about the effects of climate change. In addition, arthropods are widely and indispensably integrated into arctic systems and make up a large part of the diet of birds migrating to the Arctic in summer to breed which supports the importance of gaining more knowledge about their prosperity (Danks 1992, Tulp & Schekkerman 2008).

During the analysis of the pitfall trap samples of 2018 and 2015, the most abundant groups corresponded to the groups presented in the existing database: Collembola (Sminthuridae, Hypogastruridae, and Isotomidae), Diptera (Chironomidae, Sciaridae, Mycetophilidae, and Brachycera), Hymenoptera (Ichneumonidae), and Arachnida (Acari and Araneae). The other insects occasionally found in the samples that could not be identified have been kept separately for later analysis. It is important to mention that during this project species groups were analysed individually. Different species grouped into one may react contradictory to temperature and precipitation differences, which is well worth re-examining. Also important to mention is that due to the missing statistical analysis no firm conclusions can be drawn regarding the effect of temperature and precipitation on arthropod abundance in this report.

From supplementary table 2 in the Appendices, it can be taken that the groups Sciaridae, Mycetophilidae, and Hypogastruridae substantially present the same pattern every year. The other groups are less predictable, the different summers show a wide range of intra- and inter-seasonal variability in terms of timing, duration, and magnitude of peak abundance. This corresponds to the earlier findings in Jesse Jorna's report (2016) and the study of Elise Biersma (n.d.). Weather data from Meteorologisk Institutt et al. was consulted for one of the most outstanding daily outliers that were seen in all arthropods (9-11 July 2018), to see if it could be explained by the weather conditions at that time (i.e. temperature, precipitation, and wind speed). The data shows an average temperature of 5,9 °C, precipitation of 17,6 mm and wind speed of 4,0 m/s during this interval and studying the interval of 1 July – 19 July reveals that the precipitation on these particular 3 days was quite high (supplementary fig. 4).

Interpreting the figures leads to the hypotheses that high temperature positively affects the populations of Mycetophilidae, Ichneumonidae, Acari, and Sminthuridae. A negative influence is seen in the abundance of Chironomidae, Sciaridae, Isotomidae, and Hypogastruridae. Although this effect does not seem to be very strong at first, when looking at the course of the entire dataset from 2008 until 2018 (table 2), a period in which temperature evidently rose, members of the Chironomidae and Sciaridae families become less present in the catches, while the numbers of Mycetophilidae and Sminthuridae are increasing (supplementary fig. 5). This agrees with the previous statements. However, this cannot be said about Hypogastruridae and Isotomidae, whose course throughout the ten years differ from the analysis between two opposite years regarding temperature. An in-depth analysis showed a, contrary to expectations raised by the first analysis, weak positive effect of temperature on the abundance of Hypogastruridae throughout the entire dataset (2008-2018). However, when 2018 (a particularly wet year) is not considered, there is a weak declining trendline. It is an interesting topic for further research to examine if precipitation could overshadow the effect of temperature on Hypogastruridae abundance.

According to Jesse Jorna's findings (2016), temperature had a stimulating effect on all individual Dipteran groups as well as the abundance of Acari. Collembolan and Araneid abundance were not affected. This does not correspond with the findings presented in this report, since the Dipteran families Chironomidae and Sciaridae seem to experience a repressive effect of rising temperatures on insect abundance, just as the Collembolan family Isotomidae. Jesse further states in his report that in 2016, the families of Chironomidae and Mycetophilidae were no longer affected by increasing temperatures, but rather related to the date in the summer season. Since this project did not take the influence of specific dates in the season on arthropod abundance into account, these findings cannot be supported or rejected in this report. Jesse also mentioned that the abundance of Brachycerans was related to temperature, which was not seen in the analysis between 2014 (a cold year) and 2015 (a warm year) in this report, but looking at the entire dataset, they do show an increase in abundance over the years (supplementary fig. 5).

When looking at precipitation, rainfall appears to be a limiting factor for most arthropod groups, with the exception of Mycetophilidae, Isotomidae, and Hypogastruridae (again) as the most deviant. An in-depth analysis of the Hypogastruridae family shows a weak positive trend of precipitation on the abundance of Hypogastruridae throughout the decade. The general limiting effect of rainfall on arthropod abundance agrees with the findings of Jesse in 2016, apart from him stating that Mycetophilidae, Collembolan family, and Acari abundance were not affected. A statistical analysis will show if the findings in this report significantly differ from the findings of Jesse. Interesting is that the seasonal abundance of Hypogastruridae and Isotomidae seem to increase over the studied years (2008-2018). Since rising temperatures seem to have a negative effect on their prosperity, but precipitation stimulates their abundance, it would be interesting to investigate if one of these weather factors dominates. Other factors, such as wind, should be considered too for a more complete measurement of the effect of weather circumstances.

Gillespie et al. (2020), looking at prey availability for Arctic birds, also mentioned a significant decline in summer abundance of, relevant here, Araneae, Chironomidae, Sciaridae, Mycetophilidae, and Ichneumonidae during the period of 1996-2016. This corresponds to the results in this report, with the exception of Mycetophilidae abundance. Gillespie et al. refer to a relationship between lower arthropod abundance in years with earlier timing of snowmelt and reduced soil moisture.

An even more recent interpretation of the same database (24-years of data on Arctic arthropod abundance from Zackenberg, Greenland) was published by Høye et al. (2021). They found a nonlinear pattern of trends in arthropod abundance and diversity, with total abundance gradually decreasing during 1996-2014, followed by a sharp increase. The opposite pattern was seen at family level, indicating an increasing dominance of a small number of taxa. The responsibility for these findings was not given to summer temperature, but rather to the conditions during the winter and fall, and positive density-dependent feedbacks. As aptly written in their paper: “Together, these data highlight the complexity of characterizing climate change responses even in relatively simple Arctic food webs.” (Høye et al. 2021).

To further explore the subject of prey availability, Tulp and Schekkerman presented their findings on prey availability for Arctic birds regarding climate change in 2008. The hatching of shorebird chicks is ideally timed in the period that there is enough food available supporting their survival, and the modelling of Tulp and Schekkerman indicated that the peak of arthropod abundance had become earlier over the past decades and with it, also the period with sufficient food availability for the birds. The width of this period might be more important than the phenological mismatch between chick’s hatching and the peak of arthropod abundance (Reneerkens 2016), but the length of it has not changed (Tulp & Schekkerman 2008). These findings are supported by a more recent study of Saalfeld et al. (2019), meaning that the peak of arthropod abundance is still shifting due to a warming climate. Due to day-to-day variations in weather making food abundance very unpredictable, shorebirds seem to anticipate to this uncertainty by starting to breed as soon as the snow has sufficiently melted (Meltofte et al. 2007). Thus, decades of ongoing climate change have created a selective pressure on shorebirds to nest early, but the arrival of shorebirds at their breeding site is likely limited by their migratory schedules, causing still unknown long-term consequences for their chicks’ survival due to a trophic mismatch (Saalfeld et al. 2019).

Although the importance of innovative research into the effect of climate change on Arctic arthropods and therefore on the birds that are dependent on them is well known now, conducting this kind of research is very time-consuming and cost restricted on account of field work and species identification (Hansen et al. 2016). In the publication of Hansen et al., it was suggested that the results of less sampling throughout the season could be quite accurate: up to 72 percent of arthropod richness in a full season of sampling could be detected in just one week, with a well-thought-out planning. Considerations in mind, using and optimising this method in further research could provide cost reduction as well as fill in gaps in our knowledge on how biodiversity is affected by climate change across multiple sites in the Arctic.

The aim of this report was to improve understanding and/or gain additional knowledge of the activity of Arctic arthropods in changing weather conditions over a period of a small decade. Repeatedly mentioned in the literature and likewise seen in the results of this project, is that arthropod composition is highly affected by day-to-day weather changes, making it hard to discover a trend in the small decade of collecting samples. Interpreting the analysed years apart (with a temperature or precipitation label) or grouped as a set could also deliver different (contradictory) results. Therefore, it is interesting to subsequently perform multiple statistical analyses on the data to explore the effect of different weather circumstances on arthropod abundance throughout the studied years and to determine the significance of the presented effects of temperature and precipitation on the studied taxa. In addition, the examination of daily arthropod abundance in relation to weather data can also be interesting, just like the influence of wind, of which I could not find any recent reports.

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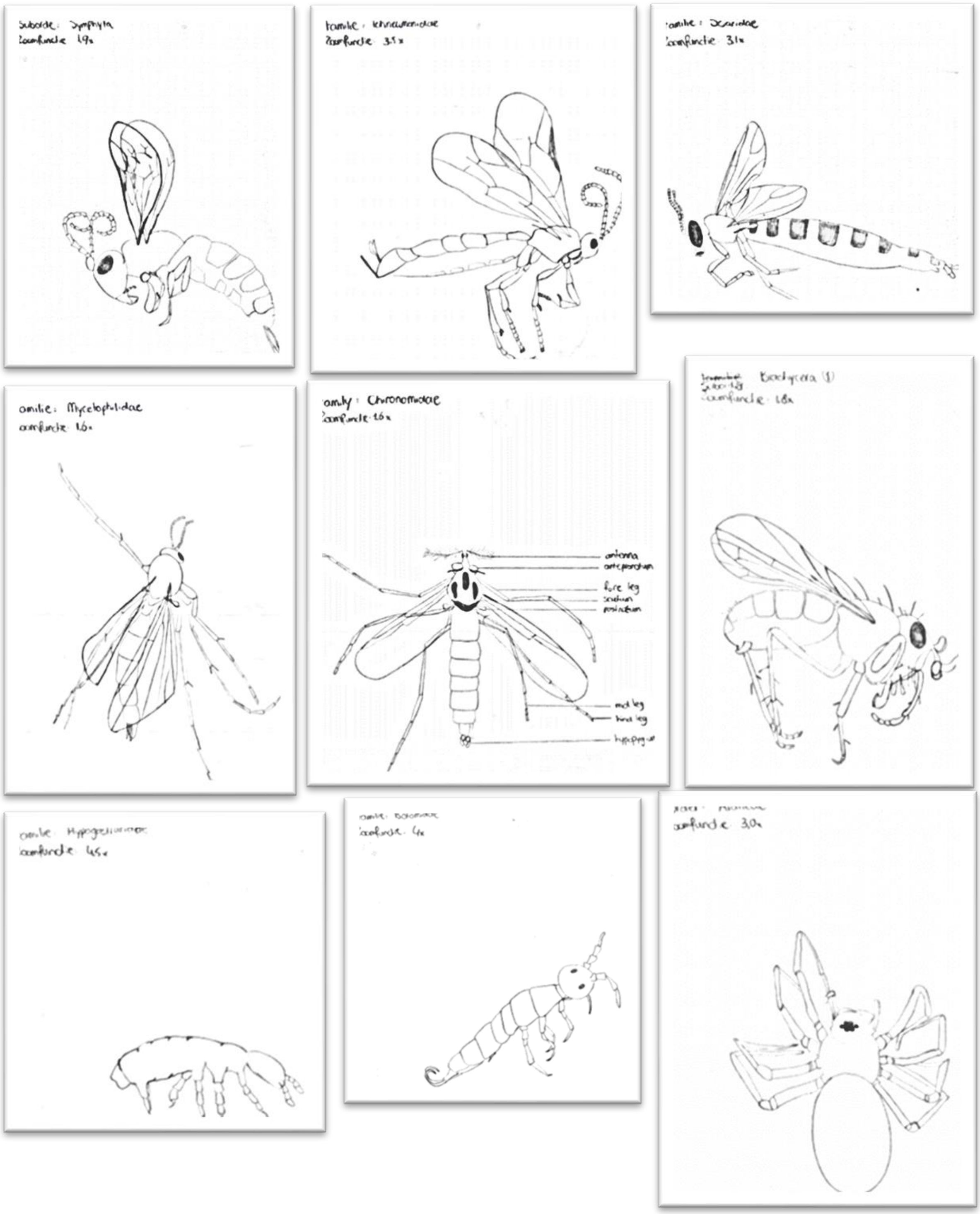
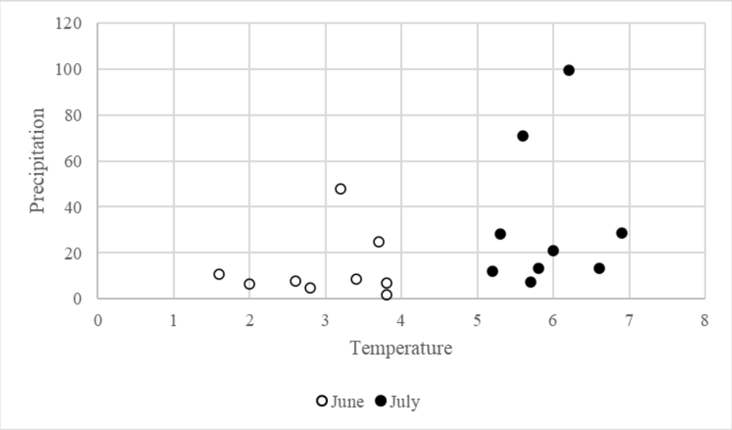
Appendices



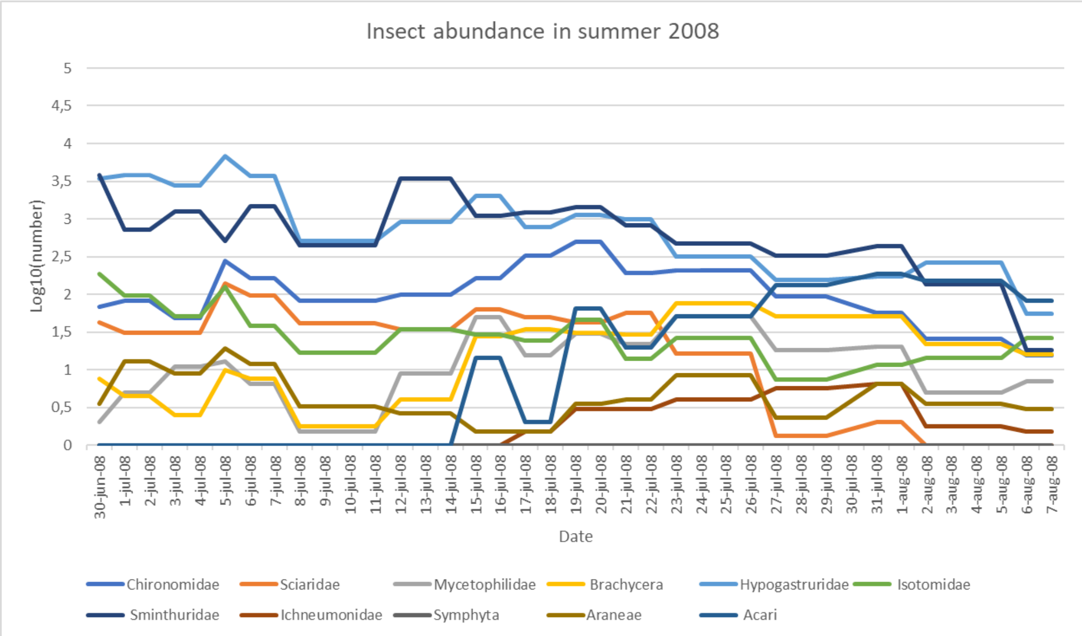
SUPPLEMENTARY FIG. 1. Handmade drawings of some of the insects made before the start of the project, to promote the recognition of the insects.

SUPPLEMENTARY TABLE 1. An overview of the mean temperatures and mean precipitation in the months of June and July in Ny-Ålesund for all analysed years (2008-2018). The table is sorted by increasing temperature to make the corresponding chart easier to read.

Mean temperature (°C) in June	Mean precipitation (mm) in June	Year
1,6	10,6	2009
2	6,4	2014
2,6	7,6	2008
2,8	5	2010
3,2	48	2013
3,4	8,6	2018
3,7	24,9	2012
3,8	1,7	2015
3,8	6,9	2016
Mean temperature (°C) in July	**Mean precipitation (mm) in July**	**Year**
5,2	12,1	2008
5,3	28,3	2014
5,6	70,8	2013
5,7	7,5	2010
5,8	13,4	2012
6	21	2009
6,2	99,4	2018
6,6	13,2	2015
6,9	28,8	2016



SUPPLEMENTARY FIGURE 2. Temperature (in °C) plotted against precipitation (in mm) during the analysed years (2008-2018) in Ny-Ålesund. Dots at the top left represent cold, wet years; dots at the top right represent warm, wet years (e.g. 2013 and 2018); dots at the bottom left represent cold, dry years (e.g. 2008, 2009 and 2014); dots at the bottom right represent warm, dry years (e.g. 2015 and 2016).


Insect abundance in summer 2008
5
4,5
4
3,5
3
2,5
2
1,5
1
0,5
0
Log10(number)
30-jun-08
1-jul-08
2-jul-08
3-jul-08
4-jul-08
5-jul-08
6-jul-08
7-jul-08
8-jul-08
9-jul-08
10-jul-08
11-jul-08
12-jul-08
13-jul-08
14-jul-08
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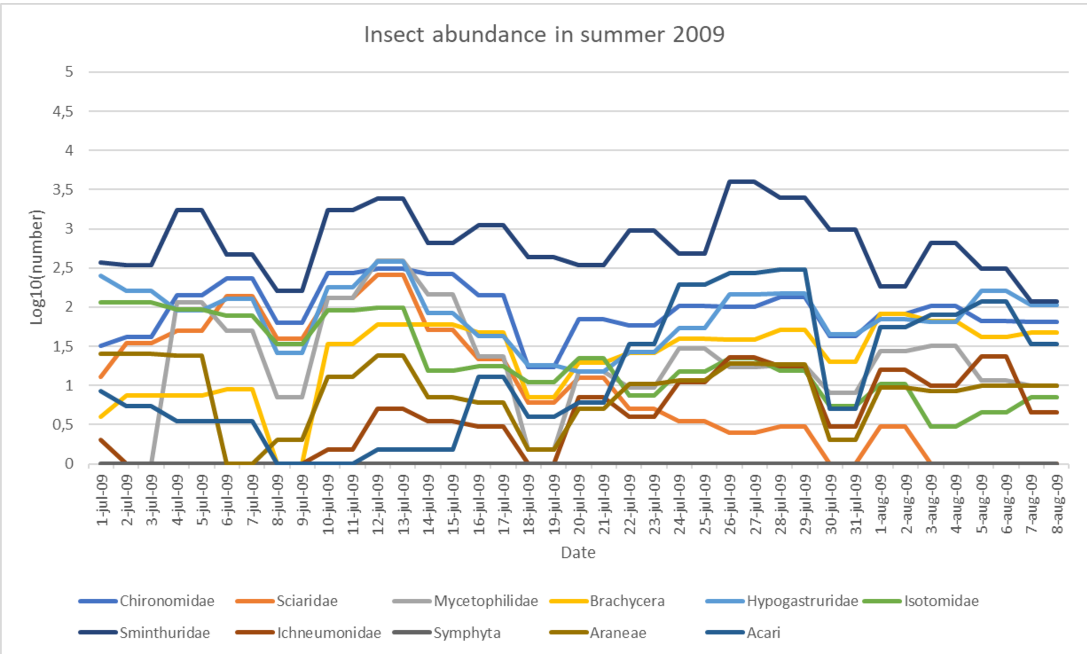
25-jul-08
26-jul-08
27-jul-08
28-jul-08
29-jul-08
30-jul-08
31-jul-08
1-aug-08
2-aug-08
3-aug-08
4-aug-08
5-aug-08
6-aug-08
7-aug-08
Date
Chironomidae
Sciaridae
Mycetophilidae
Brachycera
Hypogastruridae
Isotomidae
Sminthuridae
Ichneumonidae
Symphyta
Araneae
Acari


Insect abundance in summer 2009
5
4,5
4
3,5
3
2,5
2
1,5
1
0,5
0
Log10(number)
1-jul-09
2-jul-09
3-jul-09
4-jul-09
5-jul-09
6-jul-09
7-jul-09
8-jul-09
9-jul-09
10-jul-09
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25-jul-09
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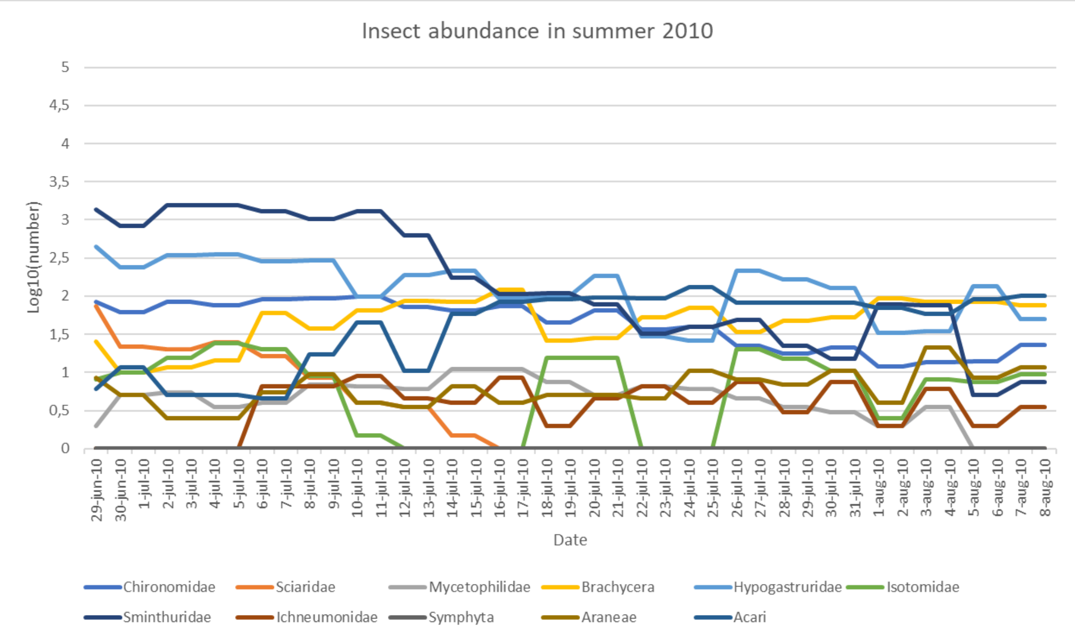
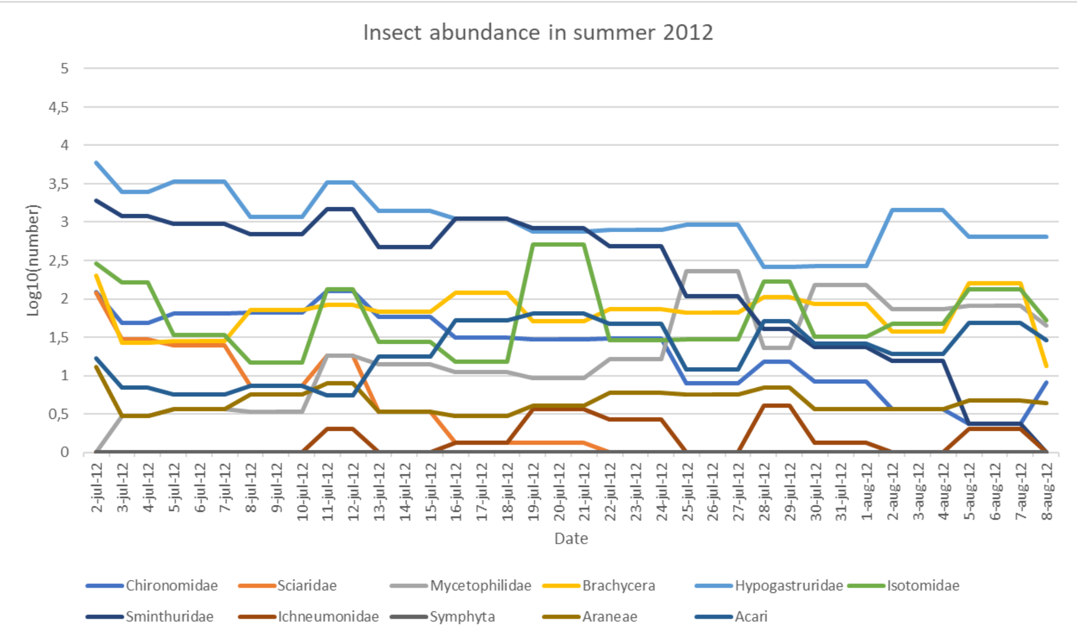
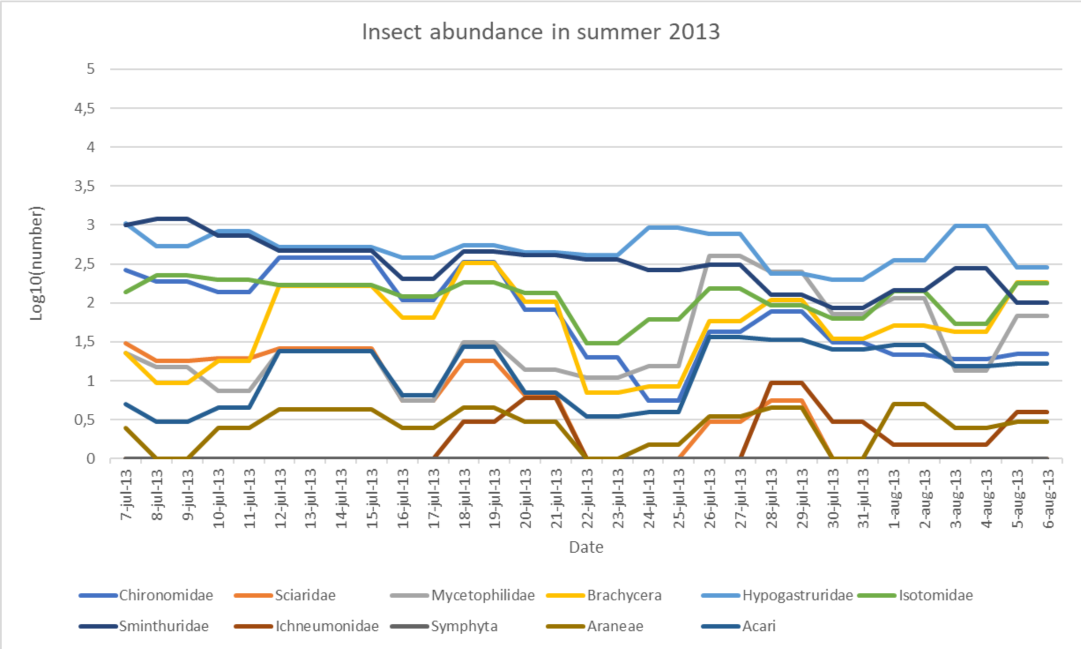
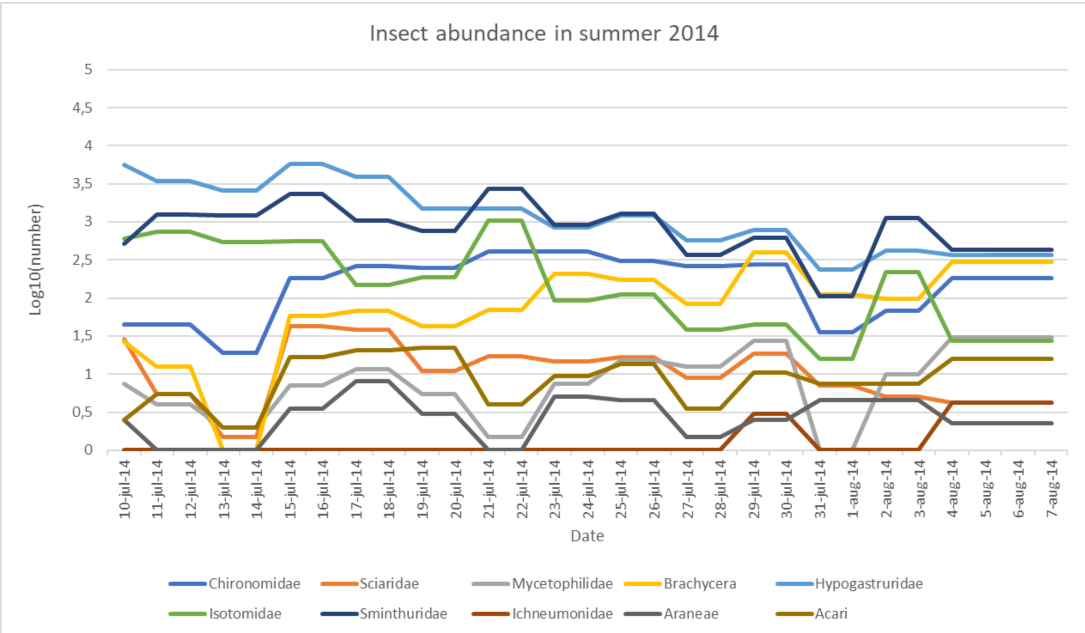
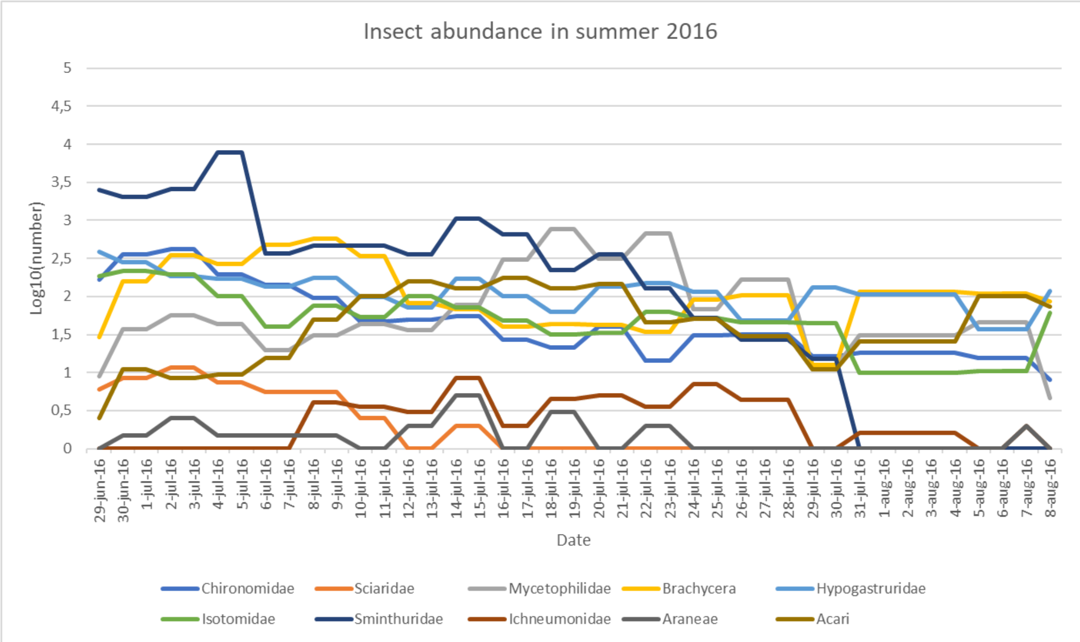
27-jul-09
28-jul-09
29-jul-09
30-jul-09
31-jul-09
1-aug-09
2-aug-09
3-aug-09
4-aug-09
5-aug-09
6-aug-09
7-aug-09
8-aug-09
Date
Chironomidae
Sciaridae
Mycetophilidae
Brachycera
Hypogastruridae
Isotomidae
Sminthuridae
Ichneumonidae
Symphyta
Araneae
Acari


Insect abundance in summer 2010
Log10(number)
Date
Chironomidae
Sciaridae
Mycetophilidae
Brachycera
Hypogastruridae
Isotomidae
Sminthuridae
Ichneumonidae
Symphyta
Araneae
Acari


Insect abundance in summer 2012
Log10(number)
Date
Chironomidae
Sciaridae
Mycetophilidae
Brachycera
Hypogastruridae
Isotomidae
Sminthuridae
Ichneumonidae
Symphyta
Araneae
Acari


Insect abundance in summer 2013
Log10(number)
Date
Chironomidae
Sciaridae
Mycetophilidae
Brachycera
Hypogastruridae
Isotomidae
Sminthuridae
Ichneumonidae
Symphyta
Araneae
Acari


Insect abundance in summer 2014
Log10(number)
Date
Chironomidae
Sciaridae
Mycetophilidae
Brachycera
Hypogastruridae
Isotomidae
Sminthuridae
Ichneumonidae
Araneae
Acari



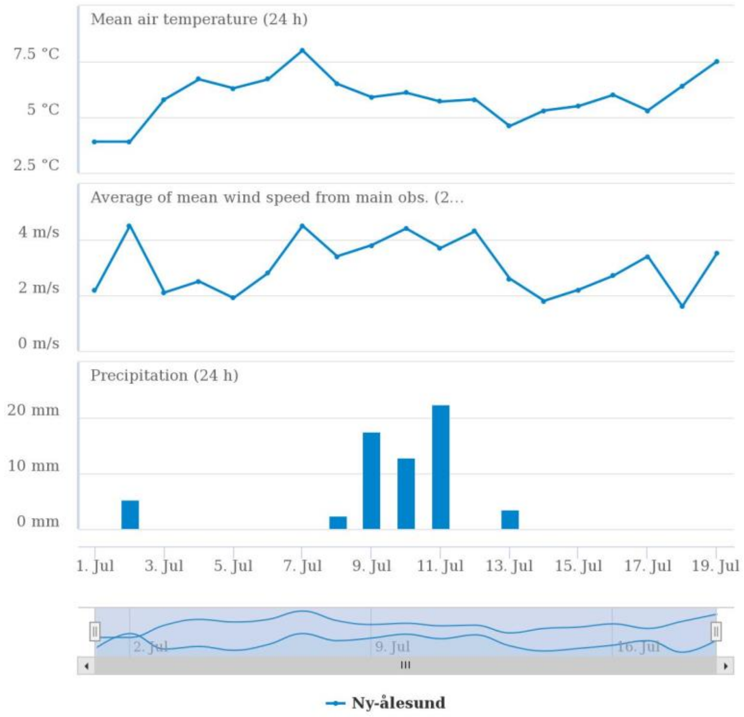
SUPPLEMENTARY FIGURE 3. Abundance of Arctic Arthropods. The y-axis indicates the number of caught individuals per species group in logarithm. The x-axis shows the same range of dates in all studied years: 2008, 2009, 2010, 2012, 2013, 2014, and 2016 from the top down (interval is calculated to1 day; start date is June 29 or the next day with data; the end date is August 8).

SUPPLEMENTARY TABLE 2. An overview of the assessed course of the arthropods during the analysed years, interpreted from the graphs of supplementary figure 2. P = peak; A = ascending; D = descending; U = unknown (no trend). The families Sciaridae, Mycetophilidae, and Hypogastruridae show the least variation over time.

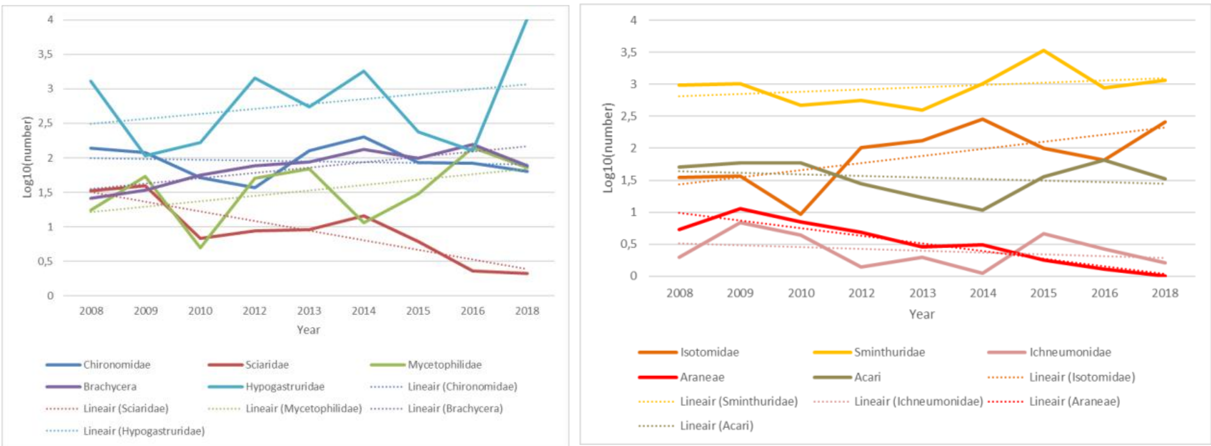
Species / Year	Chironomidae	Sciaridae	Mycetophilidae	Brachycera	Hypogastruridae	Isotomidae	Sminthuridae	Ichneumonidae	Araneae	Acari
2008	P	D	P	P	D	D	D	P	P	A
2009	P	P	P	A	D	D	U	A	U	P
2010	D	D	P	A	D	U	D	U	A	A
2012	D	D	P	U	D	U	D	U	U	P
2013	D	D	P	P	D	U	D	U	U	U
2014	P	D	U	A	D	D	U	U	P	U
2015	D	D	P	U	D	D	P	A	U	A
2016	D	D	P	P	D	D	D	P	P	P
2018	D	P	P	U	D	D	D	P	U	A

SUPPLEMENTARY TABLE 3. The mean number of insects per group per day during the summer season of the analysed years in logarithm.

Species / Year	Chironomidae	Sciaridae	Mycetophilidae	Brachycera	Hypogastruridae	Isotomidae	Sminthuridae	Ichneumonidae	Araneae	Acari
2008	2,141	1,524	1,241	1,415	3,108	1,549	2,986	0,301	0,732	1,711
2009	2,076	1,595	1,728	1,534	2,028	1,569	3,004	0,839	1,053	1,766
2010	1,716	0,833	0,699	1,750	2,225	0,968	2,673	0,643	0,845	1,775
2012	1,572	0,940	1,701	1,888	3,154	2,010	2,751	0,146	0,681	1,450
2013	2,108	0,964	1,843	1,943	2,735	2,120	2,595	0,301	0,462	1,225
2014	2,302	1,158	1,064	2,122	3,258	2,450	3,009	0,041	0,491	1,029
2015	1,929	0,792	1,477	1,992	2,373	2,001	3,531	0,663	0,255	1,558
2016	1,921	0,362	2,149	2,199	2,109	1,820	2,939	0,431	0,114	1,814
2018	1,805	0,322	1,859	1,884	4,014	2,415	3,065	0,204	0,000	1,521



SUPPLEMENTARY FIGURE 4. Weather data showing the mean air temperature, average of mean wind speed, and precipitation during the interval of 1 July – 19 July 2018 in Ny-Ålesund (Meteorologisk Institutt et al. n.d.).



SUPPLEMENTARY FIGURE 5. The course of all insect groups over the studied years (2008-2018) with trendlines. The abundance of Chironomidae, Sciaridae, Araneae, and Ichneumonidae appears to decline during the years, while abundance of the other species groups appear to be increasing.