

# A faunistic study of the amphipod-fauna of Hjeltefjord, West-Norway



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June 2019

Front cover photo: *Epimeria parasitica* M. Sars, 1858 through Leica DFC 425 Stereo microscope. Photo: Christine Østensvig

## Acknowledgements

First and foremost, I would like to offer a special thanks to my supervisor Anne Helene Tandberg for introducing me to the amazing world of amphipods, and for giving me the opportunity to learn so much about them. I am deeply grateful for all your encouragement, your support and wise words. Thank you for all your invaluable help during the lab work and during the writing of this thesis. To my supervisor Hans Tore Rapp, thank you for all the great advice you have given me in the writing progress. Thank you for always taking the time to answer even the smallest of questions, and for always helping me when I needed it.

Furthermore, I would like to thank Katrine Kongshavn for all the big and small things you have helped me with during this thesis, everything from photographing amphipods to making maps in GIS. Thank you for all the encouraging and fun conversations we had in the lab. To Luis Martell, thank you for all your help with the sampling, and for all the fun we had during the field work. I would like to thank the University Museum of Bergen for letting me use their facilities and resources to conduct this study. I also thank the crew of F/F Hans Brattström for all the help they have given me with the collection of my samples.

I would also like to thank Robert Martyn for your great help with the CTD-data. I am very grateful you took time to help me with the data and for the R script. I thank Wim Wader for letting me use the identification key he created for amphipod families in the north-Atlantic, and for helping me with problems I ran into during my work in the lab. I would also like to thank Anne-Nina Lörz for helping me find literature that was very useful in this study.

To all my friends at my study hall, thank you for the constant encouragement, for the much-needed study breaks and for all the fun conversations we've had the last year. It's been a long way, but we did it! I would like to give a special thanks to my parents. You have always supported me no matter what I wanted to do. Thank you for all the help you have given me throughout my years as a student. I thank my family and friends for all the support and encouragement they have given me.

To Jakob, thank you for always believing in me, and for all your support.

## Summary

Amphipods are a large and highly diverse order of benthic invertebrates. Their great variety in habitat selection, morphology, geographical range and feeding strategies makes them an important ecological group in marine soft sediments. Because their presence is important for the uphold of marine food webs through transfer of energy, it is essential to environmentally monitor these. This study focused on investigation of a community of amphipods in a fjord with the hope of contributing to the improvement of environmental monitoring conducted in Norwegian fjords. This is done by doing a thorough inventory of the fauna present at a fixed site in Hjeltefjorden, West-Norway and investigating the possible presence of seasonal variation. Lastly, it is discussed whether the seasonal variation is due to sampling efforts or actual biological factors.

Nine samplings were collected in the time span between November 2017 to October 2018, with two replicates taken at each sampling. All samples were collected with an RP-sled. In addition, CTD-measurements were collected to assess abiotic factors at the study site. A total of 73 species from 29 families were identified showing a high diversity in species present. The family Ampeliscidae was most abundant in all samples and represented 48 % of all specimens collected. Two different indices of biodiversity showed no significant difference in the biodiversity between the sampling replicates. Species richness and species evenness varied between replicates, showing the highest richness in November and the highest evenness in April.

The differences in species richness and abundance found throughout the year of sampling seems to be a result of both biological factors and sampling effort. Algal blooms appear to have a large impact on the community in autumn as this season had the highest species richness, highest abundance and many juveniles. Species within the same family showed similar variation in abundance, but there seems to be no shared variation pattern in the community. However, some variety in sampling effort could have affected the number of specimens collected. To give more certain results, more sampling over a larger time span should be conducted as this could reveal other patterns in the variation of the amphipod-fauna, and therefore improve the methods used for environmental sampling of these in Norwegian fjords.

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# 1 Introduction

A significant part of the oceanic bottom is covered in sediments, from finer muds to coarse gravel (Snelgrove, 1997). In these sediments we find a vast variety of benthic (bottom-living) invertebrates. These organisms have adapted to different life strategies and they hold important ecological roles in their ecosystem. One important group within these benthic invertebrates are the Amphipoda. Many species from this group contribute to the transfer of energy from lower to higher trophic levels. They control other trophic levels by feeding on the lower and by serving as a food source for higher levels. As they have such an ecologically important role, it is important that these populations are studied thoroughly as impacts on them could have serious consequences for the entire food web (Valiñas et al., 2014).

## 1.1 Amphipoda

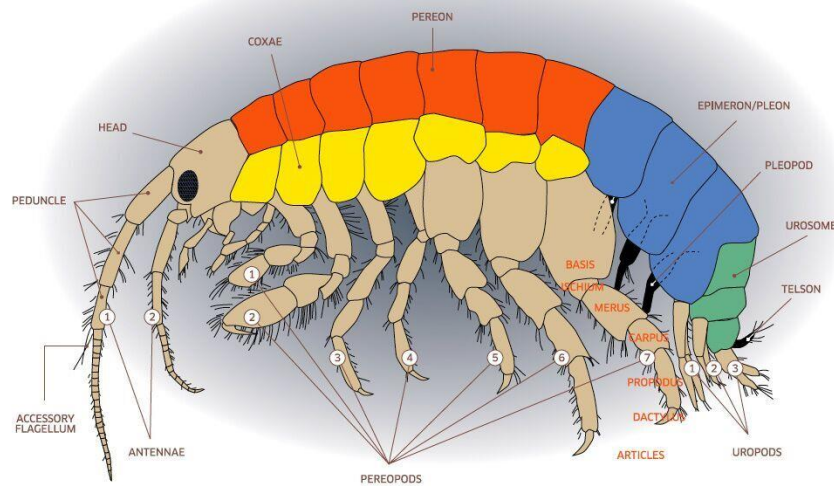
Amphipoda Latreille, 1816 (Crustacea: Malacostraca) is a large and highly diverse order with over 10 000 species found worldwide (Horton et al., 2019). Its members exhibit much variation within feeding strategies, geographical range, habitat and morphology (Carlton, 2007, Lowry and Springthorpe, 2010, Thomas, 1993). Due to large variation in morphology, there has been many disagreements in creating a taxonomic system for the amphipods. According to Schram (1986), the original description by Latreille included only what was later named suborder Gammaridea. After the order was erected by Latreille, there followed a time with many discussions as to how the taxonomy within the order should be structured. Some suborders were taken out and placed in other taxonomic groups, while others changed taxa within the order. Dana (1852) redescribed the amphipoda, and erected three suborders – Gammaridea, Caprellidea and Hyperidea. Later, the suborder Ingolfiellidea was added to the order as well. The three latter suborders have always been easily defined as their own groups due to remarkable differences in characters. Hyperidea has a very distinct shape of the head and reduced mouth parts. Caprellidae have reduced pereopods 3 and 4 and no coxal plates. Ingolfiellidea have reduced pleopods and uropod (Schram, 1896). All species and families who did not have these easily defined characters were together placed in Gammaridea (Lowry and Myers, 2013).

The current accepted taxonomy in the World Register of Marine Species (WoRMS) (Horton et al., 2019) today is presented by A.A. Myers and J.K. Lowry in a series of three papers (Myers and Lowry, 2003, Lowry and Myers, 2013, Lowry and Myers, 2017). The authors made several changes to the earlier accepted taxonomy by changing both suborders and lower taxa.

Ingolfiellidea was lifted to being its own order and separated from Amphipoda. Hyperiidea remained as its own suborder, while suborder Gammaridea was divided into four new suborders, Amphilochidea, Senticaudata, Colomastigidea and Hyperiopsidea. In addition, a small suborder with only four species, Pseudoringolfiellidea was established. Other authors, such as d'Udekem d'Acoz and Verheye (2017) have called the validation of the new division of suborders, especially the new suborder Senticaudata, into question. Therefore, the current taxonomy presented today is still under discussion (Verheye et al., 2016, d'Udekem d'Acoz and Verheye, 2017, Myers and Lowry, 2018).

Amphipods are found all the way from the sublittoral zone and down to deep waters (Carlton, 2007). Caprellids (family Caprellidae) are strictly marine or estuarine, cyamids (family Cyamidae) are ectoparasites found on whales or dolphins, and hyperiids (family Hyperiididae) are strictly pelagic (Carlton, 2007). Gammarid amphipods (earlier suborder Gammaridea, now suborders Amphilochidea, Senticaudata, Colomastigidea and Hyperiopsidea) is by far the most abundant and most common group of amphipods. They can occur in marine, brackish, and freshwater habitats, as well as damp terrestrial habitats. Gammaridean amphipods are often small in size and free-living. Some species live right above (hyperbenthic), some live on (epibenthic), and some can live in the sediments, where some species can create tube formations. Others live on seaweeds and other algae, and some reside in other invertebrate hosts (Thomas, 1993). There are several features used to characterize the order of Amphipoda. Commonly, they are identified by being laterally compressed, but this can be slightly misleading, as the family Cyamidae is not shaped this way (Barnard and Karaman, 1991a). The “typical” amphipoda has several body segments; a head, a thorax and a tail segment (figure 1.1). The head has two pairs of antennae (antenna 1 and antenna 2). The thorax consists of seven segments with each segment holding one pair of pereopods used for moving (Lincoln, 1979). The two first leg pairs are often differently shaped as they are evolved to be used for feeding, these are often called gnathopods (Enckell, 1980). The tail segment consists of three uropods used for swimming and a telson (Lincoln, 1979).





After Barnard and Karaman, 1991

**Figure 1.1:** Generalized Amphipoda. Ill: Ola Reibo after figure 1 in Barnard and Karaman (1991)

Peracarida, of which amphipoda is a part, are crustaceans that do not produce free-swimming larvae (Schram, 1986). The peracarids are often small in size but are highly abundant and diverse as almost 40 % of all crustaceans are part of this group (Thomas, 1993). The offspring undergo complete development within a marsupium, and emerges with a complete set of appendages, an internal digestion system and a thoracic circulatory system as juvenile individuals (Schram, 1986). The eggs are produced and retained within an oostegite marsupium, which is located at the female's abdomen. In addition, they often have specific habitat requirements, which often leads to a restricted spread of the populations (Thomas, 1993). These factors will likely affect the ability of amphipods to spread across the environment.

## 1.2 Seasonal variation

Seasonal variations in benthic invertebrates are often a result of both biological and abiotic factors in the marine environment. In this study the locality which is investigated is a fjord, a habitat which is very common, especially in the northern hemisphere. In this environment there are several factors that affect the presence of species and populations.

A fjord is described as a deep estuary which has been modified by land-based ice. Fjords are created by the retreat of glaciers and the fluctuations of oceanic water (Syvitski et al., 1987). Fjords are often divided into two types; sill fjords and open fjords (Breen, 1990). Sills marks the deep basin of the fjord (Farmer and Freeland, 1983). The sill will affect the exchange of the water masses (Farmer and Freeland, 1983, Syvitski et al., 1987). An open fjord does not have

this obstacle and therefore no hinder of water exchange. In the innermost part of the fjord, the water mass is mostly dominated by fresh water from river flow, while the outermost part is mostly affected by tidal currents which brings in more saline water to the fjord (Kaiser et al., 2011). The water masses in a fjord is therefore composed of different salinity levels which affect the circulation of water throughout the seasons. During the summer, when there is a higher influx of freshwater, there will be a distinct layer on top of the fjord composed of the less dense water (Breen, 1990). The tides from the ocean will lead more saltwater into the fjord and increase the mixing of the water body.

Temperature is another important factor for the environment in a fjord. A difference in temperature throughout the seasons will create thermoclines, which is defined as a distinct layer of different temperature (Breen, 1990). When the top layer of a fjord is heated up during the summer, a shallow thermocline will arise and separate the warm and cold water. When this layer is cooled down during the autumn and winter, there will be a more uniform temperature in the water which will allow for increased mixing in the fjord. The mixing of the water is also affected by other factors such as winds and currents.

Several biological factors are important to include when investigating the presence of organisms. These include competition, access to mates, and of course, food availability. Within the order Amphipoda there is great variation in feeding strategies. Some of the species are herbivores, feeding on plant material, some are detritivores, feeding on decomposed material, and some are scavengers, feeding for example on dead animals (Lowry and Springthorpe, 2010). These different feeding methods can help give a further understanding of when different species will be present as their ability to survive and reproduce are a result of their food availability.

For scavengers, their food availability is little dependent on seasonality. For detritus feeding organisms on the other hand, seasonality has a great impact on their food source. Benthic detritivores are dependent on the downfall of organic matter. This often happens after algal blooms. Before the biomass from these blooms become available to the benthos, it needs to fall through the water column. The sedimentation rate (the rate of which particles fall down the water column) varies greatly between different water masses and is dependent on factors such as ocean currents (Spetland et al., 2007). It is therefore a considerable time span between the blooms of algae and when the biomass becomes available to the benthos.

The increased availability of food in a community will often increase the rate of reproduction in organisms as their energy uptake is enhanced. The time spent by an amphipod to reproduce varies greatly between species as their life spans and life cycles are quite different. Some species have annual cycles, while others have cycles of two or three years (Węśławski and Legeżyńska, 2002, Nygård et al., 2010). In Svalbard, Nygård et al. (2010) investigated the annual routines of the amphipod *Onisimus litoralis* which has a two-year life cycle. The species was shown to have a period of mating and egg-carrying which lasted through a period of seven months (November-May). Węśławski and Legeżyńska (2002) showed that arctic amphipods had life cycles that varied between one and four years. The results showed that the brooding period where eggs and embryos were found in the marsupium varied from four to seven months. Another study conducted by Skadsheim (1984) investigated the life cycle of *Gammarus oceanicus* and *G. salinus* in the Oslofjord. *G. salinus* had a breeding period from December to May, and from June to October. There was no definite conclusion to the breeding period of *G. oceanicus*, but a possible breeding period occurred from December to May. Nair and Anger (1979), however, found that the average incubation time of eggs in the amphipod *Jassa falcata* in Helgoland was only about 9-16 days with a total life span of 149-246 days depending on temperature. Thus, there is a great variety in strategies utilized by amphipods, and this needs to be taken into account when investigating seasonal variation of a community.

Because benthic invertebrates are easily affected by changes in their habitat and they exhibit several important characters, data from benthic communities are often used to classify the conditions of an area during environmental monitoring (Johansen et al., 2018, Pearson and Rosenberg, 1978). They are often less mobile than pelagic organisms, they have different responses when exposed to stress, their life spans are relatively long, and they are an important part of food webs and nutrient cycling from sediments to the pelagic column (Dauer, 1993). However, sampling for environmental monitoring is normally only conducted once a year, and perhaps not as often as annually. In addition, the sampling is often conducted as a quantitative analysis using equipment such as a grab. With the use of these methods, it is hard to correctly assess the status of the amphipod-community in the area (Brattegard and Fosså, 1991). Therefore, semi-quantitative sampling gear would be a better method to assess the community of amphipods. Equipment such as a sled would be better for the sampling of hyperbenthic fauna, as it will not exert the same pressure as a grab, which will force the light hyperbenthic organisms out of the sample. However, this method is still not adequate for good replicability, and so new and more improved methods are still needed (Brattegard and Fosså, 1991).

The method used herein for surveying the amphipod-fauna in fjord throughout the seasons of a year has to my knowledge, never been conducted before in a west-Norwegian fjord. The results of this study can possibly contribute to give a better understand of the seasonality and abundance peaks of an amphipod community, and therefore contribute to improve how these are environmentally monitored. There are many studies of the life histories of amphipods, their place in the ecosystem and some seasonal variation (Enequist, 1949, Grabowski et al., 2007, Nygård et al., 2010, Peer et al., 1896), but there is still more to learn about the strategies utilized by amphipods. There is still much uncertainty around when the different amphipod species reproduce, what they eat, where they live and when the different stages of their life cycles take place. By investigating the species composition and abundance through seasons, we might be able to learn more about some of these matters.

### 1.3 Aim of this study

The aim of this study can be described through the following objectives:

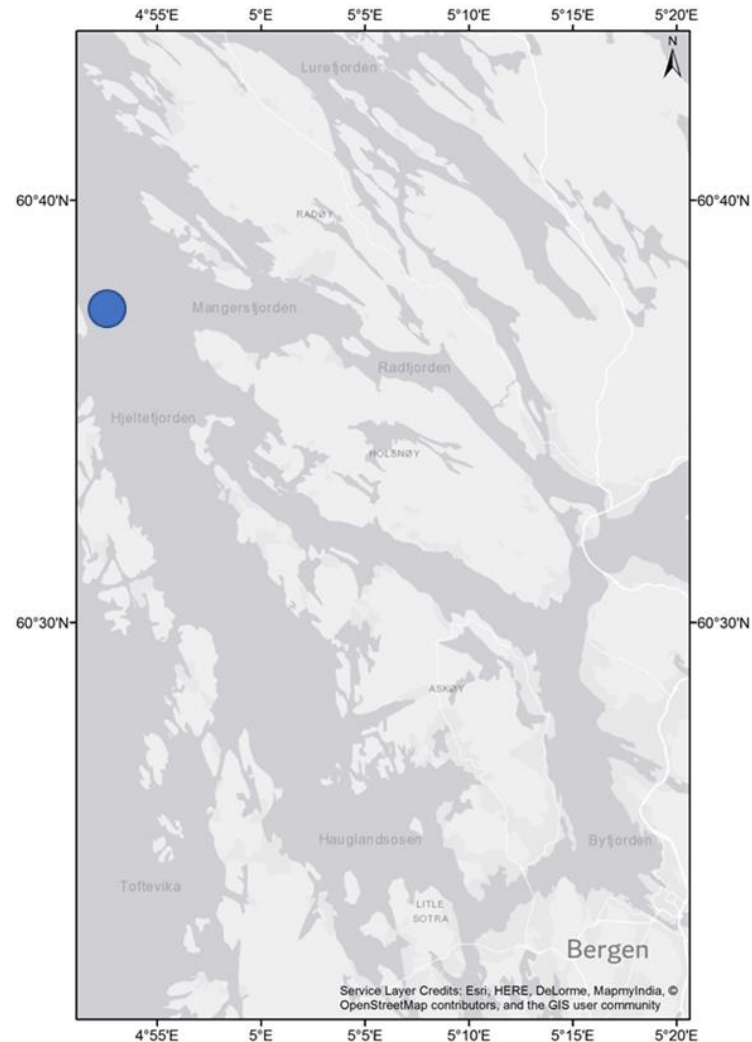
The first objective is to do a thorough inventory of the diversity of amphipods of a fixed site in Hjeltefjorden. The second objective is to investigate whether there is a seasonal variation in the presence of species and the abundance of each species. Third, it will be discussed if the possible seasonal variation is due to sampling methods or effort, or if there is an actual biological explanation to the variation.

## 2 Methods

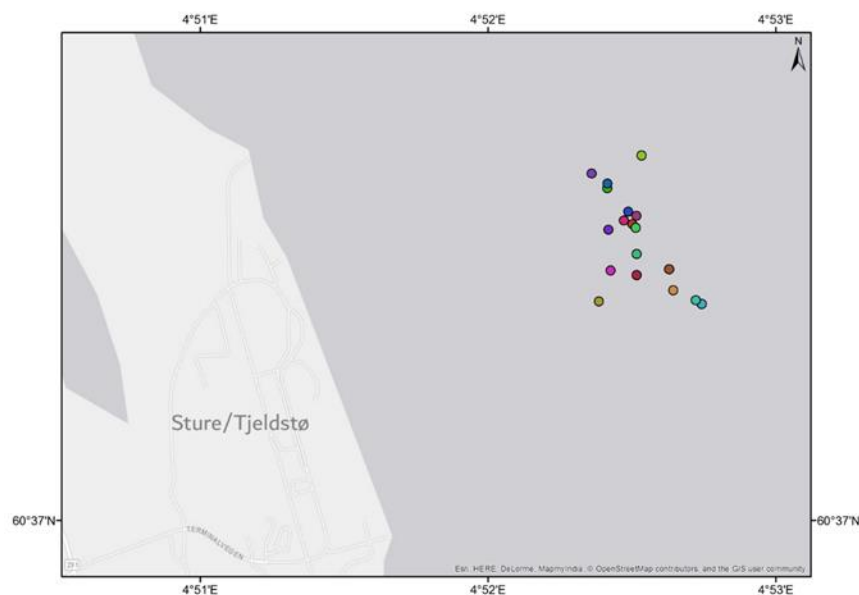
### 2.1 Study area

The area sampled in this study is located in Hjeltefjorden, a fjord northwest of Bergen, Norway (figures 2.1 and 2.2). Hjeltefjorden connects with Byfjorden towards Bergen to the south, and to the open sea to the north. The total length of the fjord is approximately 40 km (Lännegren, 1980). The depth of the fjord varies from 400 m in the northern area to 200 m in the central and south part of the fjord, and at the northern end there is a sill at 200 m depth. There is both southbound and northbound currents in the fjord (Lännegren, 1980). The fjord is quite open but is still given some protection from the land area of Tjeldstø which is located to the west. The bottom is consistent of soft sediments composed mostly of sand and some mud. There is a fair amount of organic matter present, which could indicate that the velocity of the flow in the area is not very high.

The sampling was conducted during a one-year period from November 2017 to October 2018. All samples were collected within a perimeter of four kilometres. The samples were collected in the research vessel F/F Hans Brattström. Samples were collected in November and December 2017 and February, March, April, May, June, August and October 2018. Two replicates were taken each sampling day, giving a total of 18 replicates.



**Figure 2.1:** Sampling location in the Hjeltefjord, western Norway

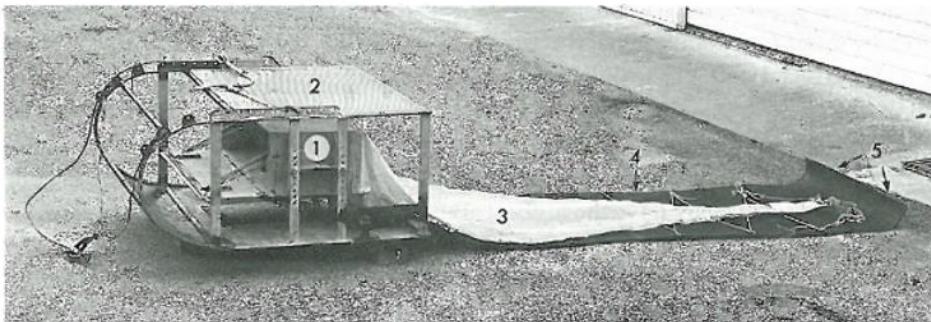


**Figure 2.2:** Overview over all sampling replicates. Each point represents the start coordinates

For all replicates, coordinates, the time the gear spent on the bottom, the depth of the sampling and the direction of the haul were documented (table 2.1). Herein, the area of study will be referred to as the sampling site, the monthly sampling will be referred to as samples, and the two different sled hauls per sampling are referred to as replicates.

## 2.2 Sampling gear

The samples were collected using an RP-sled, which is an epibenthic sampler. Epibenthic sampling refers to the sampling of fauna residing right above the sea floor. The sled used in this work is constructed after Rothlisberg and Percy (1976), with some modifications. The sled is described and modified by Brattegard and Fosså (1991). The sampler consists of a sampling box in the front with an opening that is approximately 33 cm high and 100 cm wide. The sled is connected to a plankton net (0.5 mm mesh size) with a codend attached to the end of the net (Brattegard and Fosså, 1991). The net and codend is connected to a rubber mat through attachment holes for protection of the gear (figure 2.3). The sled is deployed from the vessel using winches, and then slowly lowered down to the sea floor and hauled along the bottom for roughly 10 minutes with a speed of approximately 1 knot. Due to the upturned runners on the front by the opening of sled, turbulence is created, which allows for the top layer of sediments to be whirled up (Gage and Bett, 2005). Hence, the epibenthic fauna right above the sediments are drawn into the sled, through the net and into the codend.



**Figure 2.3:** RP epibenthic sled. (1) Sampling box. (2) Perforated top-plate. (3) Sampling net. (4) Rubber mat. (5) Holes for attachment of lead weights. Illustration from Brattegard and Fosså (1991)

For seven of the nine months that were sampled, CTD measurements were collected to investigate some of the abiotic factors of the sea water, and how these factors change throughout the seasons. Two different CTD probes were used, both of the model SD204. The probe was changed after the three first months (first used in March). Some problems were encountered during the first use of a new probe, and so the measurements were not conducted properly, resulting in measurements only going 30 m down the water column.

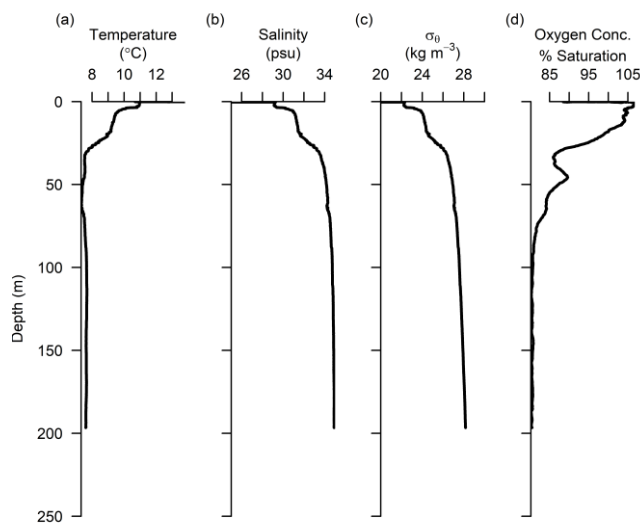
**Table 2.1:** Sample data collected for each replicate retrieved at the sampling site. Comments refers to lack of data from the sampling. \* Refers to lack of data for end coordinates. \*\* Refers to loss of sample due to strong winds. \*\*\* Refers to the use of new codend as previously used codend was lost during sampling

Month	Date	Replicate ID	Coordinates start	Coordinates end	Time	Depth	Direction	Replicate description	Comment
November	13.11.17	HB-2017-11-13-1-RP	60°37.505 N 4°52.501 E	-	10.50- 11.00	227 m	N-S	Full codend. Moderate size of sample	*
		HB-2017-11-13-2-RP	60°37.392 N 4°52.643 E	-	12.54- 13.04	209 m	N-S	Almost full codend. Moderate size of sample	*
December	13.12.17	HB-2017-12-13-1-RP	60°37.519 N 4°52.515 E	60°37.442 N 4°52.675 E	10.12- 10.22	226- 208 m	N-S	Half-full codend. Moderate size of sample	
		HB-2017-12-13-2-RP	60°37.622 N 4°52.533 E	60°37.533 N 4°52.440 E	10.50- 11.05	211- 227 m	N-S	Full codend. Moderate size of sample	
February	19.02.18	HB-2018-02-19-1-RP	60°23.591 N 4°52.359 E	60°37.406 N 4°52.652 E	12.48- 13.01	220 m	N-S	Moderate size of sample	
		HB-2018-02-19-2-RP	60°37.511 N 4°52.472 E	60°37.408 N 4°52.651 E	13.28- 13.39	229- 206 m	N-S	Moderate size of sample	
March	10.03.18	HB-2018-03-10-1-RP	60°37.369 N 4°52.742 E	60°37.485 N 4°52.511 E	09.30- 09.39	209- 230 m	S-N	Very large sediment sample.	
		HB-2018-03-10-2-RP	60°37.426 N 4°52.426 E	60°37.550 N 4°52.373 E	10.12- 10.21	210- 223 m	S-N	Very large sediment sample	
April	05.04.18	HB-2018-04-05-1-RP	60°37.454 N 4°52.516 E	60°37.556 N 4°52.433 E	10.15- 10.24	222- 229 m	S-N	Little sediment, very high presence of copepoda	
		HB-2018-04-05-2-RP	60°37.428 N 4°52.629 E	60°37.535 N 4°52.567 E	10.46- 10.57	209- 230 m	S-N	Little sediment, very high presence of copepoda	

<b>May</b>	23.05.18	HB-2018-05-23-1-RP	60°37.418 N 4°52.516 E	60°37.196 N 4°52.836 E	10.50- 11.05	202- 229 m	S-N	Moderate size of sample	
		HB-2018-05-23-2-RP	60°37.566 N 4°52.414 E	60°37.413 N 4°52.616 E	11.33- 11.47	226- 211 m	N-S	Moderate sample size, little sediment	
<b>June</b>	08.06.18	HB-2018-06-08-1-RP	60°37.574 N 4°52.415 E	60°37.318 N 4°52.702 E	10.53- 11.04	222- 213 m	N-S	Small sample, no sediment	
		HB-2018-06-08-2-RP	60°37.495 N 4°52.418 E	60°37.305 N 4°52.635 E	11.34- 11.45	220- 192 m	S-N	-	**
<b>August</b>	11.08.18	HB-2018-08-11-1-RP	60°37.499 N 4°52.512 E	60°37.423 N 4°52.662 E	10.20- 10.29	225- 207 m	N-S	Little sediment, moderate size of sample	***
		HB-2018-08-11-2-RP	60°37.526 N 4°52.487 E	60°37.379 N 4°52.710 E	10.48- 11.01	228- 207 m	N-S	Little sediment, moderate size of sample	***
<b>October</b>	19.10.18	HB-2018-10-19-1-RP	60°37.375 N 4°52.722 E	60°37.499 N 4°52.631 E	10.28- 10.34	222- 211 m	N-S	Little sediment, moderate size of sample	***
		HB-2018-10-19-2-RP	60°37.473 N 4°52.385 E	60°37.473 N 4°52.791 E	11.05- 11.17	214- 221 m	S-N	Little sediment, moderate size of sample	***



CTD data is lacking for two of the sampled months, December and October. In December, measurements were taken, but due to problems with the extraction of the data, it was lost. In October, the CTD haul could not be conducted due to very strong winds. Depth, temperature, salinity and density were recorded. In March, April, May, June and August, the percentage of oxygen saturation was recorded as well. Recordings were taken either each second or every other second from the surface and until the CTD probe reached the sea floor and back up. Figure 2.4 shows an example of recorded data from one sampling.



**Figure 2.4:** Example of a CTD profile collected at the sampling site. Temperature, salinity, density and percentage oxygen saturation are plotted against depth. These measurements are collected in May (HB-2018-05-23)

### 2.3 Sampling protocol

When the sled was hauled back up on deck, the content of the codend and net was flushed into a bucket with water. The sample was split into two fractions: the decant and the sediment fraction. This was done by filling the bucket with sample up with water to allow the light organisms to float up to the surface. The sample was then poured over a sieve (500  $\mu\text{m}$ ). The sieve was constantly held in water to prevent damage to the organisms in the sieve. When all the water was poured out, the bucket was refilled so that more organisms could float up. This procedure was repeated until no more organisms floated up. This part of the sample was fixated as the decant fraction. The rest of the sample (the heavier organisms and the sediment) was fixated on its own as the sediment fraction. All samples were fixated in 96 % ethanol. When not being handled, the samples were stored in a cold storage (4°C) to preserve the organisms. The ethanol containing the samples was changed after a few days to make sure that water from the samples did not dilute the ethanol.

## 2.4 Handling of samples and species identification

After sampling, all amphipods from the different replicates were sorted out from the rest of the sample. The specimens were first sorted into families by the use of an identification key for gammaridean amphipod families in the north Atlantic (Tandberg and Vader, 2018a). Further, all specimens, where possible, were identified to species. All identification work was performed from January 2018 to February 2019 at the invertebrate collections at the University Museum of Bergen. Some specimens were discarded as defining characters (such as urosome or pereopods) were lacking. Some specimens were only identified down to family or genus due to the identifying characters being too similar within the genus to be able to separate the species. Where a genus has more than one unknown species, the individuals are given the name “genus\_CHO\_sp-number”. The unknown species are given unique identifiers to make sure that they are comparable to other studies at a later stage. Each specimen was counted to enable reports of how many specimens there was of each species using a variety of keys and literature. Table 2.2 shows the literature used to identify individuals of each family in this thesis. Herein, the naming of species follows the accepted taxonomy from World Register of Marine Species (Horton, et al., 2019). All material collected in this study will be deposited in the University Museum of Bergen.

**Table 2.2:** Literature used for species identification in this thesis. The families are arranged in a taxonomic order

Family	References
Ampeliscidae	Barnard & Karaman (1991a), Enequist (1949) Lincoln (1979), Sars (1890-95)
Amphilochidae	Tandberg & Vader (2018b)
Aristiidae	Sars (1890-95), Stephensen (1935)
Atylidae	Lincoln (1979), Sars (1890-95)
Cyproideidae	Sars (1890-95)
Epimeriidae	Beerman et al. (2018), Lörz & Coleman (2015), Sars (1890-95)
Eusirdae	Sars (1890-95), Thurston (2009a)
Leucothoidae	Sars (1890-95)
Liljeborgiidae	d’Udekem d’Acoz (2010), d’Udekem d’Acoz & Vader (2009), Sars (1890-95)
Melphidippidae	Sars (1890-95)
Oedicerotidae	Bellan-Santini et al. (1993), Bousfield & Chevrier (1996), Lincoln (1979), Sars (1890-95)
Pardaliscidae	Lincoln (1979), Sars (1890-95)
Phoxocephalidae	King et al. (2004), Lincoln (1979), Sars (1890-95)
Pleustidae	Sars (1890-95)
Scopelocheiridae	Sars (1890-95) Stephensen (1935)
Stegocephalidae	Berge & Vader (2001), Sars (1890-95)
Stenothoidae	Barnard & Karaman (1991b), Krapp-Schickel (2015), Sars (1890-95)
Stilipedidae	Sars (1890-95)
Synopiidae	Sars (1890-95)
Opisidae	Sars (1890-95), Stephensen (1935)
Tryphosidae	Sars (1890-95), Stephensen (1935), Thurston (2009b)
Uristidae	Sars (1890-95), Stephensen (1935)
Urothoidae	Lincoln (1979), Sars (1890-95)
Hyperiidae	Zeidler (2004)
Aoridae	Sars (1890-95)
Calliopiidae	Bousfield & Hendrycks (1997), Coleman (1999), Sars (1890-95)
Ischyroceridae	Sars (1890-95)
Photidae	Sars (1890-95)
Podoceridae	Lincoln (1979), Sars (1890-95)

## 2.5 Data analysis

To be able to investigate the changes in biodiversity throughout the seasons, species richness, species evenness, Shannon Weaver index of diversity and Simpson’s index of diversity was calculated. These are all measurements of how the species and the abundance of each species are distributed within each sampling replicate. All calculations were performed using R (version 3.5.0, R Core Team, 2018) and RStudio (version 1.1.447, Rstudio team 2016) with the R package Vegan (Version 2.5-5, Oksanen et al., 2019).

Shannon Weaver index of diversity was calculated using the formula

$$H' = \sum_{i=1}^S \left( \frac{N_i}{N} \right) \log_2 (N_i/N) \quad (\text{Shannon and Weaver, 1949})$$

where S = total number of species and N = total number of individuals. The index is a measurement of both evenness and richness of species at a chosen sample site (Magurran,

2004). The value for the index is most often to be found between the 1.5 and 3.5, and it rarely surpasses 4. The index value will increase as both the evenness and the richness of the sample site increases (Magurran, 2004).

Species evenness is calculated by taking the Shannon Weaver index and dividing it by the natural logarithm (ln) of the amount of species found in each replicate (ln(s)). Species evenness is always a number between 0 and 1, where 0 represent minimal evenness and 1 represents maximal evenness (Nijs and Roy, 2000).

Simpson's index of diversity was calculated using the formula

$$D = 1 - \left( \frac{\sum n(n-1)}{N(N-1)} \right) \quad (\text{Simpson, 1949})$$

Where N = total number of individuals. This index is based on probability. The index measures the probability that two random individuals drawn from an infinite sized community belongs to the same species (Magurran, 2004).

Rarefaction curves were made for all the replicates where they were combined into seasons. Rarefaction allows for the investigation of species richness. The curves show the number of species as a function of the number of samples. As sampling increase, number of species increase and the curve rises quickly until all common species are found, and the curve increase slows down. Rarefaction curves can be used to investigate whether high amounts of species in a given sample are due to the area actually having a high richness or due to sample size or sample amount (Gotelli and Colwell, 2001).

## 3 Results

### 3.1 Taxonomy

#### 3.1.1 Species identification

From the 17 different samples collected and sorted, a total of 73 species from 29 families were identified. The following species list provides information about taxonomy, species name and first description for each species. \* refers to species described as cf. \*\* refers to one species named *Byblis\_CHO\_sp.1*, where the species is one of these two in the species list. The taxonomy follows that of World Register of Marine Species (Horton et al., 2019). The species described by G.O. Sars in 1882 and 1883 are all described in the same publication (G.O. Sars, 1883). (Tanberg, AH, pers.comm (as WoRMS editor) mentioned this as the same publication).

**Order** AMPHIPODA Latreille, 1816

**Suborder** AMPHILOCHIDEA Boeck, 1871

**Family** AMPELISCIDAE Krøyer, 1842

**Genus** *AMPELISCA* Krøyer, 1842

**Species** *Ampelisca anomala* G.O. Sars, 1883

**Species** *Ampelisca brevicornis* (Costa, 1853)

**Species** *Ampelisca gibba* G.O. Sars, 1883

**Species** *Ampelisca odontoplax* G.O. Sars, 1879

**Species** *Ampelisca pusilla* G.O. Sars, 1891

**Species** *Ampelisca typica* (Bate, 1856)

**Genus** *BYBLIS* Boeck, 1871

**Species** *Byblis affinis* G.O. Sars, 1879 \*\*

**Species** *Byblis erythrops* G.O. Sars, 1883 \*\*

**Species** *Byblis gaimardii* (Krøyer, 1846)

**Species** *Byblis longicornis* G.O. Sars, 1891

**Species** *Byblis\_CHO\_sp.2*

**Genus** *HAPLOOPS* Liljeborg, 1856

**Species** *Haploops setosa* Boeck, 1871

**Species** *Haploops* sp.

**Family** AMPHILOCHIDAE Boeck, 1871

**Genus** *AMPHILOCHOIDES* G.O. Sars, 1892

**Species** *Amphilochoides boeckii* G.O. Sars, 1892

**Genus** *AMPHILOCHUS* Bate, 1862

**Species** *Amphilochus manudens* Bate, 1862

**Genus** *GITANOPSIS* G.O. Sars, 1892

**Species** *Gitanopsis bispinosa* (Boeck, 1871)

**Genus** *PARAMPHILOCHOIDES* Lincoln, 1979

**Species** *Paramphilochoides intermedius* (Scott, 1896)

- Family** ARISTIIDAE Lowry & Stoddart, 1997  
**Genus** *ARISTIAS* Boeck, 1871  
**Species** *Aristias neglectus* Hansen, 1888
- Family** ATYLIDAE Liljeborg, 1865  
**Genus** *NOTOTROPIS* Costa, 1853  
**Species** *Nototropis guttatus* Costa, 1853  
**Species** *Nototropis nordlandicus* (Boeck, 1871)  
**Species** *Nototropis smitti* (Göes, 1866)  
**Species** *Nototropis vedlomensis* (Bate & Westwood, 1862)
- Family** CYPROIDEIDAE J.L. Barnard, 1974  
**Genus** *STEGOPLAX* G.O. Sars, 1883  
**Species** *Stegoplax longirostris* G.O. Sars, 1882
- Family** EPIMERIIDAE Boeck, 1871  
**Genus** *EPIMERIA* Costa in Hope, 1851  
**Species** *Epimeria cornigera* (Fabricius, 1779)  
**Species** *Epimeria parasitica* (M. Sars, 1858)
- Family** EUSIRIDAE Stebbing, 1888  
**Genus** *EUSIRUS* Krøyer, 1845  
**Species** *Eusirus leptocarpus* G.O. Sars, 1893  
**Species** *Eusirus longipes* Boeck, 1861  
**Species** *Eusirus minutus* G.O. Sars, 1893
- Family** LEUCOTHOIDAE Dana, 1852  
**Genus** *LEUCOTHOE* Leach, 1814  
**Species** *Leucothoe spinicarpa* (Abildgaard, 1789)
- Family** LILJEBORGIIDAE Stebbing, 1899  
**Genus** *LILJEBORGIA* Bate, 1862  
**Species** *Liljeborgia ossiani* d'Udekem d'Acoz & Vader, 2009  
**Species** *Liljeborgia pallida* (Bate, 1857)
- Family** MELPHIDIPPIDAE Stebbing, 1899  
**Genus** *MELPHIDIPPA* Boeck, 1871  
**Species** *Melphidippa borealis* Boeck, 1871  
**Species** *Melphidippa macrura* G.O. Sars, 1894
- Family** OEDICEROTIDAE Liljeborg, 1865  
**Genus** *BATHYMEDON* G.O. Sars, 1892  
**Species** *Bathymedon* sp.  
**Genus** *DEFLEXILODES* Bousfield & Chevrier, 1996  
**Species** *Deflexolides* sp.  
**Genus** *MONOCULODES* Stimpson, 1853  
**Species** *Monoculodes* sp.  
**Genus** *OEDICEROPSIS* Liljeborg, 1865  
**Species** *Oediceropsis brevicornis* (Liljeborg, 1865)  
**Genus** *ROSTROCULODES* Bousfield & Chevrier, 1996  
**Species** *Rostroculodes* sp.

- Family** PARDALISCIDAE Boeck, 1871  
**Genus** *NICIPPE* Bruzelius, 1859  
**Species** *Nicippe tumida* Bruzelius, 1859  
**Genus** *PARDALISCA* Krøyer, 1842  
**Species** *Pardalisca tenuipes* G.O. Sars, 1893  
**Species** *Pardalisca* sp.
- Family** PHOXOCEPHALIDAE G.O. Sars, 1891  
**Genus** *HARPINIA* Boeck, 1876  
**Species** *Harpinia laevis* G.O. Sars, 1891  
**Species** *Harpinia pectinata* G.O. Sars, 1891  
**Species** *Harpinia serrata* G.O. Sars, 1879  
**Genus** *PARAPHOXUS* G.O. Sars, 1891  
**Species** *Paraphoxus oculatus* (G.O. Sars, 1879)
- Family** PLEUSTIDAE Buchholz, 1874  
**Genus** indet.  
**Species** indet.
- Family** SCOPELOCHEIRIDAE Lowry & Stoddart, 1997  
**Genus** *SCOPELOCHEIRUS* Bate, 1856  
**Species** *Scopelocheirus hopei* (Costa in Hope, 1851)
- Family** STEGOCEPHALIDAE Dana, 1852  
**Genus** *STEGOCEPHALOIDES* G.O. Sars, 1891  
**Species** *Stegocephaloides christianiensis* Boeck, 1871
- Family** STENOTHOIDAE Boeck, 1871  
**Genus** *STENOTHOE* Dana, 1852  
**Species** *Stenothoe megacheir* (Boeck, 1871)  
**Species** *Stenothoe* sp.
- Family** STILIPEDIDAE Holmes, 1908  
**Genus** *ASTYRA* Boeck, 1871  
**Species** *Astyra abyssi* Boeck, 1871
- Family** SYNOPIIDAE Dana, 1853  
**Genus** *SYRRHOE* Göes, 1866  
**Species** *Syrrhoe crenulata* Göes, 1866  
**Genus** *SYRRHOITES* G.O. Sars, 1893  
**Species** *Syrrhoites serrata* (G.O. Sars, 1879)
- Family** OPISIDAE Lowry & Stoddart, 1995  
**Genus** *NORMANION* Bonnier, 1893  
**Species** *Normanion sarsi* Stebbing, 1906
- Family** TRYPHOSIDAE Lowry & Stoddart, 1997  
**Genus** *HIPPOMEDON* Boeck, 1871  
**Species** *Hippomedon propinquus* G.O. Sars, 1890  
**Genus** *LYSIANELLA* G.O. Sars, 1882  
**Species** *Lysianella petalocera* G.O. Sars, 1882  
**Genus** *ORCHOMENE* Boeck, 1871  
**Species** *Orchomene amblyops* G.O. Sars, 1890

- Species** *Orchomene* sp.
- Family** URISTIDAE Hurley, 1963
- Genus** *ICHNOPUS* Costa, 1853
- Species** *Ichnopus spinicornis* Boeck, 1861
- Genus** *TMETONYX* Stebbing, 1906
- Species** *Tmetonyx acutus* (G.O. Sars, 1891)
- Species** *Tmetonyx cicada* (Fabricius, 1780)
- Species** *Tmetonyx leucophthalmus* (G.O. Sars, 1891) \*
- Family** UROTHOIDEAE Bousfield, 1978
- Genus** *UROTHOE* Dana, 1852
- Species** *Urothoe elegans* Bate, 1857
- Suborder** HYPERIIDEA Milne Edwards, 1830
- Family** HYPERIIDAE Dana, 1852
- Genus** *THEMISTO* Guèrin, 1825
- Species** *Themisto abyssorum* (Boeck, 1871) \*
- Species** *Themisto compressa* Göes, 1866
- Suborder** SENTICAUDATA Lowry & Myers, 2013
- Family** AORIDAE Stebbing, 1899
- Genus** *MICRODEUTOPUS* Costa, 1853
- Species** *Microdeutopus anomalus* (Rathke, 1843)
- Family** CALLIOPIIDAE G.O. Sars, 1893
- Genus** *LAOTHOES* Boeck, 1871
- Species** *Laothoes meinerti* Boeck, 1871
- Family** ISCHYROCERIDAE Stebbing, 1899
- Genus** *CENTRALOECETES* Just, 1983
- Species** *Centraloecetes pallidus* (G.O. Sars, 1882)
- Genus** *ISCHYROCERUS* Krøyer, 1838
- Species** *Ischyrocerus\_CHO\_sp.1*
- Species** *Ischyrocerus\_CHO\_sp.2*
- Family** PHOTIDAE Boeck, 1871
- Genus** *MEGAMPHOPUS* Norman, 1869
- Species** *Megamphopus* sp.
- Family** PODOCERIDAE Leach, 1814
- Genus** *LAETMATOPHILUS* Bruzelius, 1859
- Species** *Laetmatophilus tuberculatus* Bruzelius, 1859

### 3.1.2 Unidentified species

From all the specimens collected in this thesis, many proved to be difficult to identify. For some specimens it was not possible to give them a species name because of either high similarity between species or no matching descriptions of species. Other species have been given a species name with confere (“cf.”) because the specimen either was not completely identical to the description or because the sampling area was not the natural location of the species in with



respect to depth, bottom type or geographical range. The definition of cf. used herein is as suggested by Sigovini et al. (2016). The following descriptions show all species with uncertainty in the identification and the explanations as to why they were not allocated to a specific species.

#### *Byblis* CHO sp.1

In all replicates, specimens from the genus *Byblis* were found (total of 2267 specimens). Many of the specimens were lacking important describing characters that made it impossible to identify them to the correct species. These characters include epimeral plate 3, telson, uropod 3 and antennae. In the autumn and winter samples (November, December and February), many juvenile specimens were found. When juveniles make their way to the adult stage, they undergo allometric changes. This means that the juveniles not yet have, or do not have fully pronounced, all the characters that the adults have. Sars (1890-95) states that “The species of this genus are still more difficult to distinguish from each other, exhibiting, as they do, a very uniform appearance, and agreeing almost exactly in the structure of the last pair of pereopoda” (Sars, 1890-1895).

The characters of the unknown species made it possible that it was one of three different species; *Byblis affinis*, *B. erythropis* and *B. gaimardii*. These species had very similar traits, so there can be some difficulty in separating them. Though it is more likely that the specimens are of either the species *B. affinis* or *B. erythropis*, as some specimens with slight differences than the rest later were identified to being members of the species *B. gaimardii*. According to Sars (1890-95), it is not possible to separate them by area. Hence, the identification of these species proved to be extremely difficult, and therefore they were given the name *Byblis*\_CHO\_sp.1 (See appendix A for illustrations of specimens).

#### *Byblis* CHO sp.2

In the replicate HB-2018-08-11-2, 20 specimens of an unidentifiable species were found. The specimens had characters that were similar to both the genus *Haploops* and the genus *Byblis*. After using the key from Barnard and Karaman (1991a) the specimens were decided to be of the genus *Byblis* as the flagellum of both pair of antennae had more than 6 articles, as well as the shape and amount of hair (reaching up to the junction between ischium and basis) on pereopod 7.

According to Sars (1890-95), *Byblis* is recognizable by “Urosome short and stout. Corneal lenses, when present, two on each side. [...] Telson short and broad, and only slightly incised posteriorly” (Sars, 1890-95). These characters are consistent with the specimens found, however, they show a distinct and deep keel and a shape of uropod 3 which is more consistent with the genus of *Haploops*, and specifically the species *Haploops tubicola*. For *Haploops*, Sars states that “Corneal lenses, when present, only two, the inferior pair being quite absent” (Sars, 1890-95), which were not agreeable with these specimens. The character of the keel is not found in any of the described species of *Byblis* found in surrounding areas. The shape of epimeral plate 3 can also be linked to both genera, which makes it a difficult character to use in the determination. The specimens have therefore been assigned to the name *Byblis\_CHO\_sp.2* as it was not possible to determine the correct species of the genus (See appendix A for illustrations of the specimens).

*Haploops* sp.

In November, one specimen from the family Ampeliscidae was found (figure 3.1). It was decided to be of the genus *Haploops* as the basis of pereopod 7 was similar to that of this genus. However, the specimen did not have the correct characteristics to be any of the species that are described from our waters (Sars, 1890-95). Characters such as the shape of the eyes, the number of setae on the dorsal side (which were lacking in this specimen), the shape of epimeral plate 3 and the cleft of the telson made it impossible to identify it as any of the species found at this latitude. The specimen was therefore given the name *Haploops* sp.



**Figure 3.1:** Specimen of the genus *Haploops* which was not possible to identify further to species. This specimen was found in the decant from the second replicate sampled in November. Photo: K. Kongshavn

#### Family Oedicerotidae

The family Oedicerotidae is large and complicated. There are many genera and many species. The species within genera are often quite similar and difficult to distinguish from each other. Due to this, most specimens were only identified to genus. Within the family there is a group of genera called the “*Monoculodes* super genus” (Bousfield and Chevrier, 1996) which houses three of the genera identified in this thesis – *Rostroculodes*, *Deflexilodes* and *Monoculodes*. The genera are separated by the shape of rostrum, the gnathopods, pereopods 3 and 4 and the basis of pereopod 7 (Bousfield and Chevrier, 1996). These characters were used to identify the genera found in this study. In addition, specimens of the genus *Bathymedon* were also found. There was also a fifth genus, *Oediceropsis*. This genus has one species, *Oediceropsis brevicornis*, which is very easy to distinguish.

#### *Pardalisca* sp.

In February, two specimens of the family Pardaliscidae were found. They were juvenile and very small in size, and therefore difficult to identify. They were decided to be of the genus *Pardalisca* as the characters of the specimens agreed with the identification literature used. Due to their small size it was not possible to thoroughly examine the characters that are important for species identification, and therefore they were only assigned a genus and not a species name.

*Stenothoe* sp.

One specimen of the family Stenothoidae which was a juvenile female was found in November. The specimen was decided to be a female as there are very distinct differences between the females and males in this family (large difference in the shape of gnathopods). The specimen had similar characters to the genus *Stenothoe* (Krapp-Schickel, 2015) and was assigned there. Due to its small size and the lack of defining characters it was not possible to decide which species the specimen was a member of.

*Orchomene* sp.

At all samplings, a total of 54 specimens within the family Tryphosidae were found. They were first identified to be a part of the genus *Orchomene*, which is characterized by having subchelate gnathopods, a telson which is not very deeply cleft, and often some serration on the edge of epimeral plate 3 (Sars, 1890-95). The specimens resembled both *Orchomene pectinatus* and *Orchomene serratus* but was different than *Orchomene amblyops* which was also identified in this thesis. Due to similar characteristics between the species, it was not possible to assign them to either species, and they were therefore given the name *Orchomene* sp.

*Ischyrocerus* CHO sp.1 and *Ishcyrocerus* CHO sp.2

Specimens which were identified to be of the genus *Ischyrocerus* were found in all replicates. This genus poses the same difficulties as that of *Stenothoe* sp. The specimens were most likely females as they had very few characters that could be used to categorize them as any specific species. It was clear that there were two groups of specimens which were dissimilar, but neither could be identified down to species. They were therefore given the names *Ischyrocerus*\_CHO\_sp.1 and *Ischyrocerus*\_CHO\_sp.2.

*Megamphopus* sp.

These specimens were found in approximately half of the replicates collected. The specimens had the right characteristics to be a part of the genus *Megamphopus*. Members of this genus (and the family Photidae) have long slender bodies which can easily be damaged through sampling. Therefore, most specimens had lost important characters needed for identification. It was possible to identify them to genus, but no further. As they all had the same characters, they were together given the name *Megamphopus* sp.

### Pleustidae indet.

This family is among one of the most difficult families to identify (Barnard and Given, 1960). Only one specimen from this family was found during the identification process, and due to its difficulty, it was decided not to further identify it to genus or species.

### Eusirus cf. longipes

At the sampling in August, one specimen of the genus *Eusirus* was found. The specimen was highly similar to the other specimens from the species *Eusirus longipes*. *E. longipes* normally have two postero-dorsal teeth, one at urosomite 1, and one at urosomite 2 which is defining for this species. This specimen lacked the tooth on urosomite 1 and had a very small tooth on urosomite 3. The rest of the defining characters for the species was agreeable with that found on this specimen. As no other species in this genus has this combination of postero-dorsal teeth, the specimen was assigned to the name *Eusirus cf. longipes*.

### Tmetonyx cf. leucophthalmus

*Tmetonyx* is a genus within the family Uristidae which is easily distinguishable from other genera by having an L-shaped eye. In December, one specimen of this genus was found. The specimen had characters which was very similar to that of *Tmetonyx leucophthalmus*, but the shape of the body and some other characters were somewhat dissimilar. The specimen was therefore assigned the name *Tmetonyx cf. leucophthalmus*.

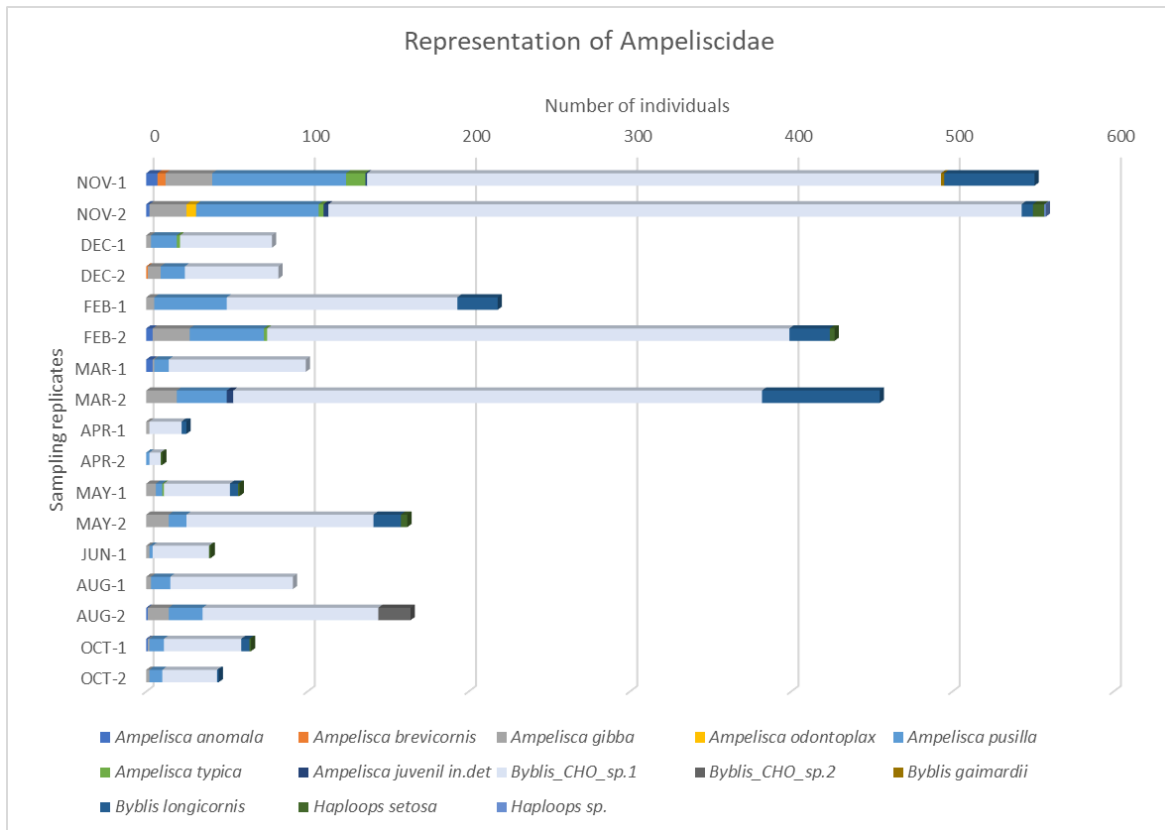
### Themisto cf. abyssorum

During all samplings except from June and October, several specimens of the family Hyperiididae were found. The specimens were decided to be of the genus *Themisto* as the characters found were agreeable with the description of the genus in the identification key in Zeidler (2004). The specimens were identified to be the species *Themisto abyssorum*, but this species is described from deeper, more cold waters than the site sampled in this thesis. No other species from the key had characters that was similar to the specimens found, and therefore they were given the name *Themisto cf. abyssorum*, as the depth and temperature of the sampling site did not agree with the normal described area for the species.

### 3.1.3 Dominant families

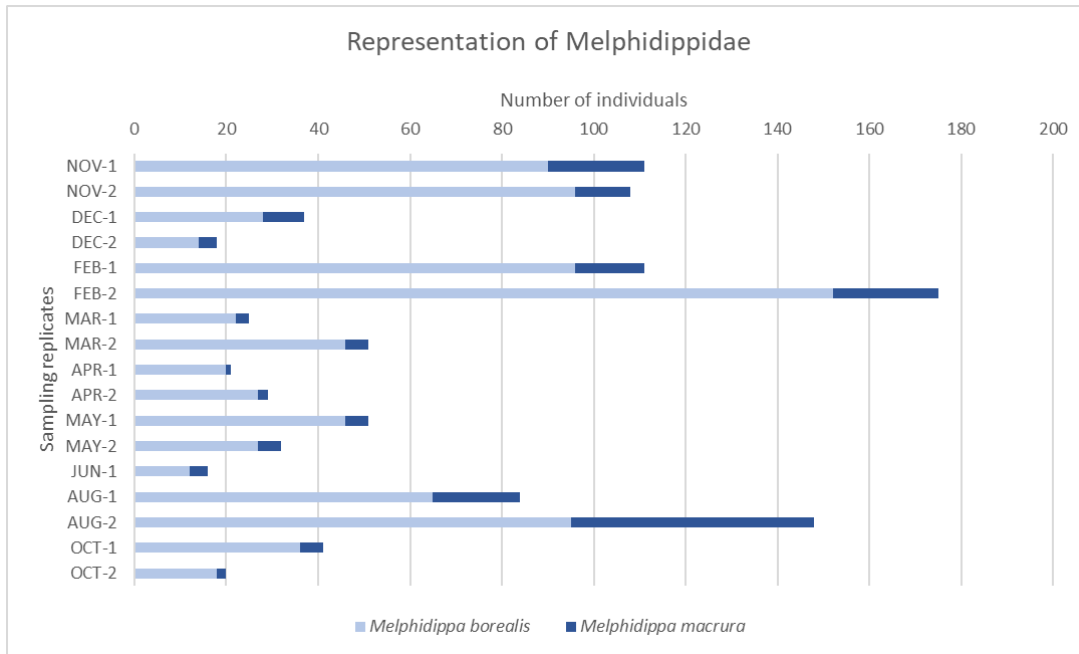
Through all sampling months, one family was considered to be especially dominant as the number of specimens were very high compared to other families. The family Ampeliscidae was represented with 3142 of the total 6520 specimens identified in total (figure 3.2). This makes

up 48% of the specimens. Specifically, the species *Byblis\_CHO\_sp.1* was represented with a total of 2267 specimens, with the highest abundance found in autumn, winter and spring (November, February and March). The other species in this family were represented by smaller numbers but were present at most samplings.



**Figure 3.2:** Representation of the family Ampeliscidae in all replicates collected

Another family with high abundance was Melphidippidae. The family counts 1078 specimens and take up 16.5 % of the total specimens sampled (figure 3.3). There were two species found from this family, *Melphidippa borealis* and *Melphidippa macrura*. *M. borealis* had a total of 890 specimens in total, while *M. macrura* was represented with a total of 188 specimens across all replicates.



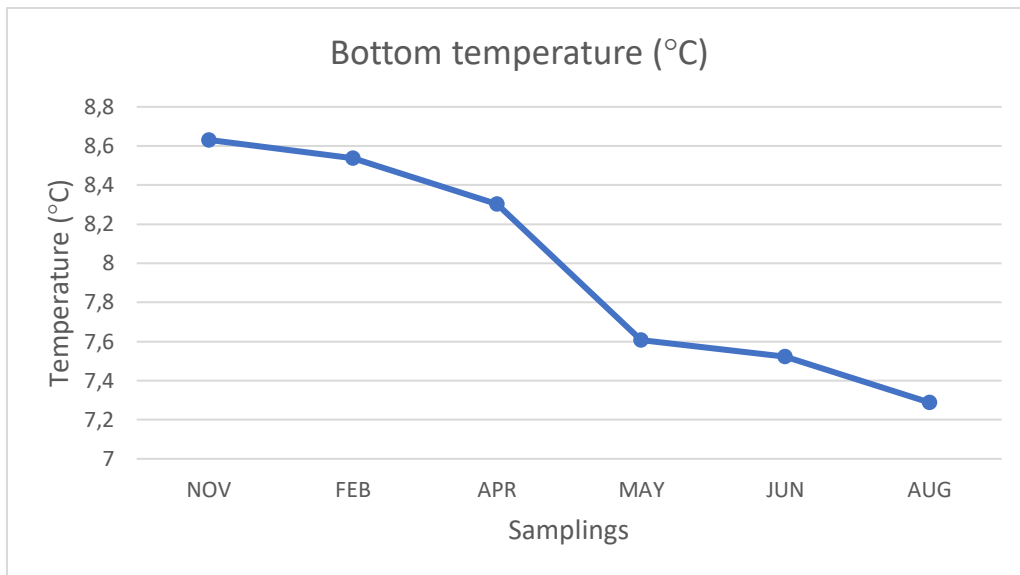
**Figure 3.3:** Representation of the family Melphidippidae in all replicates collected

### 3.2 The abiotic environment

CTD data was collected at seven of the nine samplings. Data was not collected in December (HB-2017-12-13) and October (HB-2018-10-19) either due to a faulty CTD-probe or due to weather. For each sampling, temperature ( $^{\circ}\text{C}$ ), salinity (psu) and density,  $\sigma_{\theta}$  ( $\text{km m}^{-3}$ ) were measured. In addition, the oxygen saturation (%) in the sea water was measured for five samplings. As the samples collected were benthic, the data collected close to the sea floor are most describing of the environment that the amphipod-fauna resides in. In addition, plots where the abiotic factors are plotted over time and as a function of depth (appendix B) were made.

#### 3.2.1 Temperature ( $^{\circ}\text{C}$ )

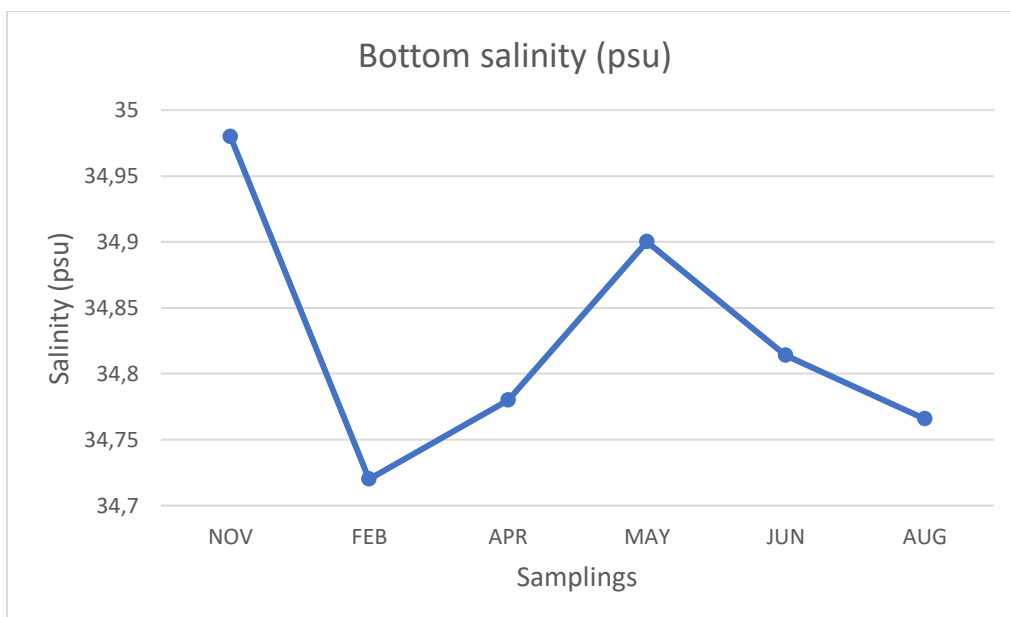
Bottom temperature showed a steady decrease in value from November (autumn) to August (summer), with a total decrease of ca  $1^{\circ}\text{C}$  (figure 3.4). The temperature had a larger decrease from November to May, and until August where it decreases less rapidly. The value recorded in March was excluded as the CTD-probe did not record values all the way down to the bottom.



**Figure 3.4:** Bottom temperature measured for each sampling with the exception of March (HB-2018-03-10) as the CTD did not measure the values at the bottom at this time

### 3.2.2 Salinity (psu)

The bottom salinity had a clear decline in salinity from November (autumn) to February (winter). After February there was an increase in the salinity until May, where it once again declined towards August (figure 3.5). The value recorded in March was excluded as the CTD-probe did not record values all the way down to the bottom.

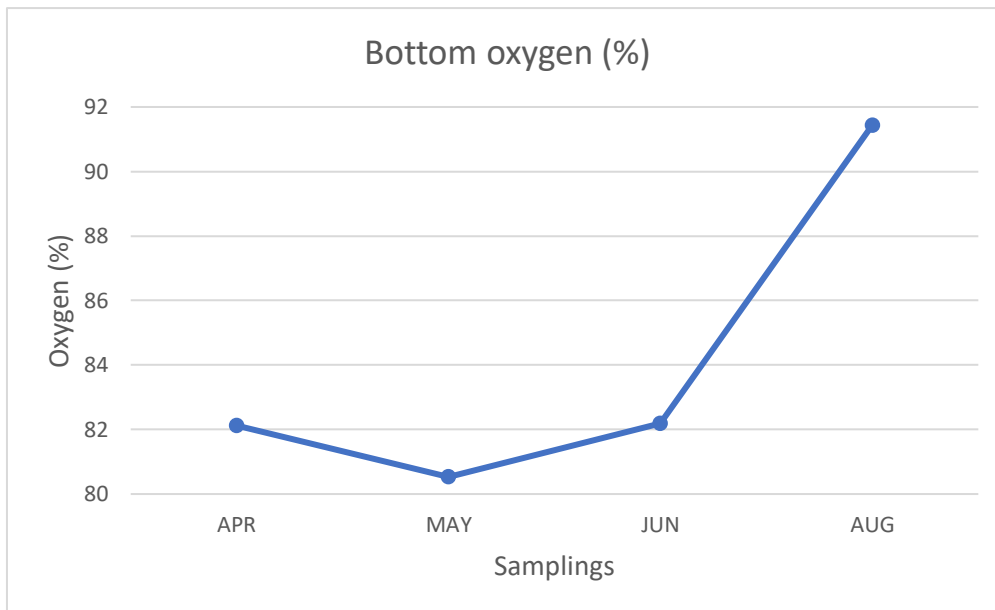


**Figure 3.5:** Bottom salinity measured for each sampling with the exception of March (HB-2018-03-10) as the CTD did not measure the values at the bottom at this time



### 3.2.3 Oxygen saturation (%)

The percentage of dissolved oxygen at the bottom was relatively stable around 82-80 % from April to June. Between June and August there was a significant increase with a change of almost 10 % (figure 3.6).



**Figure 3.6:** Percentage of dissolved oxygen measured at each sampling, with the exception of March (HB-2018-03-10) as the CTD did not measure the values at the bottom at this time. Note that oxygen saturation only was measured from March to August

## 3.3 Seasonal variation

In this study, it is of interest to investigate the possible presence of seasonal variation in the amphipod-fauna found in Hjeltefjorden. Herein, seasonal variation is measured in several ways. First one can investigate how often a species is present in the replicates taken. This will show if most species are common in the area sampled or if they are relatively rare. Second, one can investigate the changes in the abundance and biodiversity throughout the seasons to better understand the variation in community composition. This was done by calculating two indices of biodiversity, Shannon Weaver and Simpson and species evenness. For the purpose of seasonal variation, the sampling dates were sorted into seasons, where winter is composed of December and February, spring is composed of March, April and May, summer is composed of June and August, and autumn is composed of October and November.

### 3.3.1 Species presence

For the purpose of investigating species presence, the replicates were combined into months, giving two replicates per month, except for June which had one. Most species were either very

common or rare (table 3.1). 29 species were found in only one or two months during the sampling year. They are therefore seen as relatively rare at the study site. 15 species were found in all sampling months and are therefore seen as common species in this area. However, many species were found at an intermediate amount of the samplings.

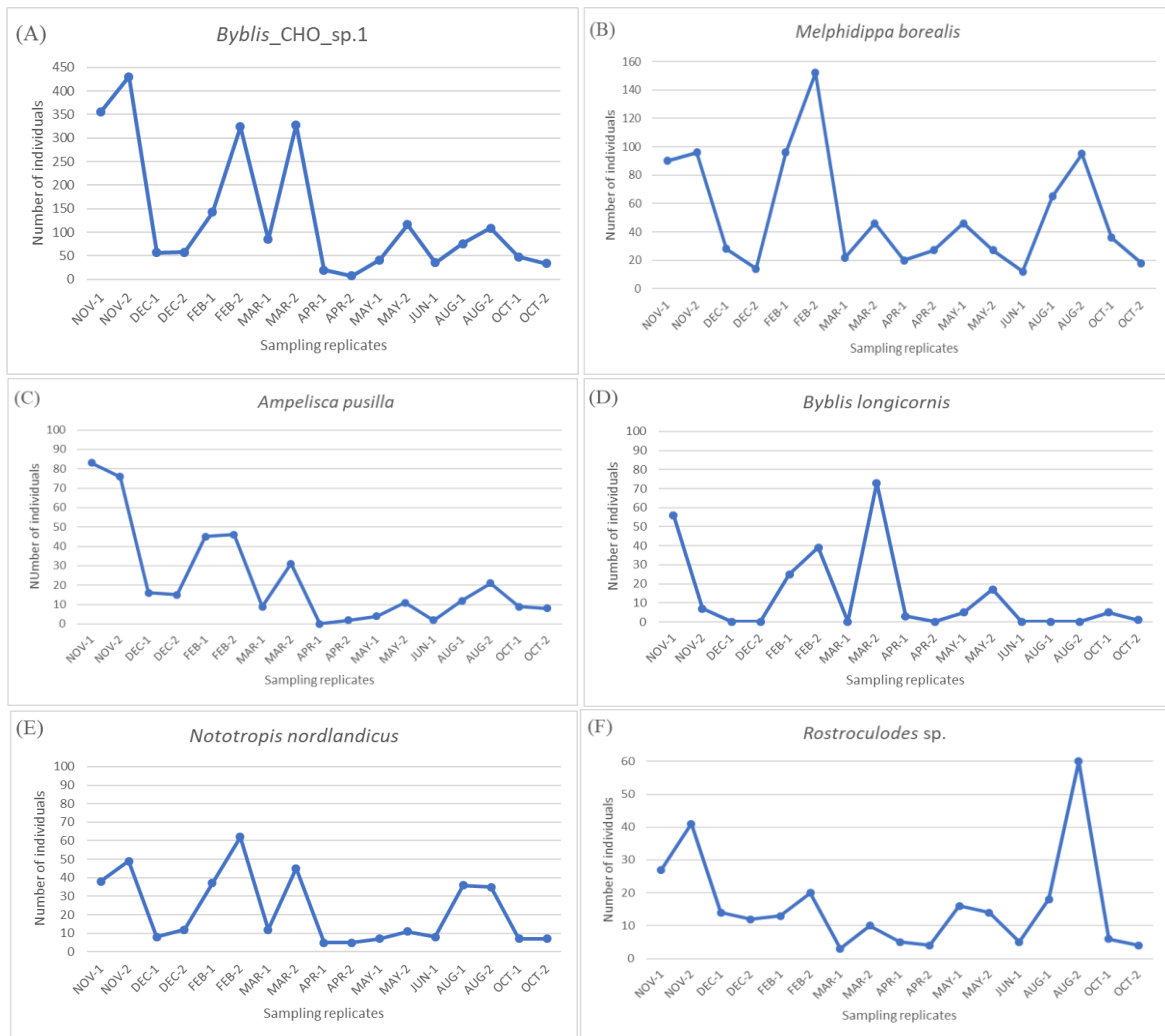
**Table 3.1:** Number of months during the sampling that each species is present in. Each month is composed of two replicates with the exception of June. The species are in an alphabetic order, first with respect to genus, and then to species

Species	No. of months with encounters	Species	No. of months with encounters
<i>Ampelisca anomala</i>	5	<i>Liljeborgia ossiani</i>	7
<i>Ampelisca brevicornis</i>	2	<i>Liljeborgia pallida</i>	6
<i>Ampelisca gibba</i>	9	<i>Lysianella petalocera</i>	2
<i>Ampelisca odontoplax</i>	1	<i>Megamphopus</i> sp.	8
<i>Ampelisca pusilla</i>	9	<i>Melphidippa borealis</i>	9
<i>Ampelisca typica</i>	4	<i>Melphidippa macrura</i>	9
<i>Ampelisca juvenil indet.</i>	2	<i>Microdeutopus anomalus</i>	7
<i>Amphilochoides boeckii</i>	6	<i>Monoculodes</i> sp.	7
<i>Amphilocheus manudens</i>	4	<i>Nicippe tumida</i>	2
<i>Aristias neglectus</i>	2	<i>Normanion sarsi</i>	7
<i>Astyra abyssi</i>	8	<i>Nototropis guttatus</i>	2
<i>Bathymedon</i> sp.	4	<i>Nototropis nordlandicus</i>	9
<i>Byblis gaimardii</i>	1	<i>Nototropis smittii</i>	1
<i>Byblis longicornis</i>	6	<i>Nototropis vedlomensis</i>	5
<i>Byblis_CHO_sp.1</i>	9	<i>Oediceropsis brevicornis</i>	9
<i>Byblis_CHO_sp.2</i>	1	<i>Orchomene amblyops</i>	7
<i>Centralocetes pallidus</i>	1	<i>Orchomene</i> sp.	9
<i>Deflexilodes</i> sp.	8	<i>Paramphilochoides intermedius</i>	1
<i>Epimeria cornigera</i>	9	<i>Paraphoxus oculatus</i>	9
<i>Epimeria parasitica</i>	1	<i>Pardalisca</i> sp.	1
<i>Eusirus leptocarpus</i>	4	<i>Pardalisca tenuipes</i>	2
<i>Eusirus longipes</i>	9	<i>Pleustidae</i> indet.	1
<i>Eusirus cf. longipes</i>	1	<i>Rostroculodes</i> sp.	9
<i>Eusirus minutus</i>	9	<i>Schopelocheirus hopei</i>	6
<i>Gitanopsis bispinosa</i>	6	<i>Stegacephaloides christianiensis</i>	3
<i>Haploops setosa</i>	6	<i>Stegoplax longirostris</i>	1
<i>Haploops</i> sp.	1	<i>Stenothoe megacheir</i>	1
<i>Harpinia laevis</i>	6	<i>Stenothoe</i> sp.	1
<i>Harpinia pectinata</i>	2	<i>Syrrhoe crenulata</i>	9

<i>Harpinia serrata</i>	1	<i>Syrrhoites serrata</i>	8
<i>Hippomedon propinquus</i>	6	<i>Themisto</i> cf. <i>abyssorum</i>	7
<i>Ichnopus spinicornis</i>	5	<i>Themisto compressa</i>	2
<i>Ischyrocerus_CHO_sp.1</i>	9	<i>Tmetonyx acutus</i>	5
<i>Ischyrocerus_CHO_sp.2</i>	1	<i>Tmetonyx cicada</i>	8
<i>Laetmatophilus tuberculatus</i>	2	<i>Tmetonyx</i> cf. <i>leucothalmus</i>	1
<i>Lathoes meinerti</i>	2	<i>Urothoe elegans</i>	6
<i>Leucothoe spinicarpa</i>	1		

### 3.3.2 Seasonal changes in species composition

Most species identified were represented in very small numbers. Some were only found once throughout the sampling period, or they were found in very few numbers or at few sampling replicates. Hence, it is not possible to describe any possible seasonal variation for these species. Some species were found in greater numbers and were present in all or most replicates (figure 3.7). These species had a great difference in their variation through the seasons, and no clear pattern is present. Appendix C shows graphs for all species that were represented with more than 10 specimens and were present in at least five of the replicates.



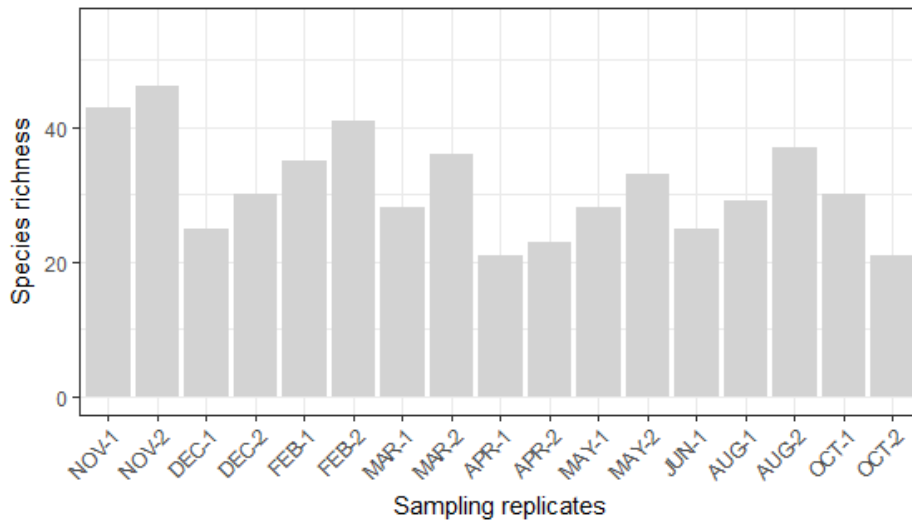
**Figure 3.7:** Variation in species abundance for a few selected species throughout the sampling year. The species curves are arranged from highest to lowest abundance. Appendix C shows graphs for all species that were represented with more than 10 specimens and were present in at least five of the sampling replicates

### 3.4 Biodiversity

For each replicate, species richness and species evenness were calculated. In addition, two different indices of diversity, Shannon Weaver and Simpson were calculated (Appendix D). This was done to be able to investigate the biodiversity of the samples, and seasons, and to be able to understand the changes in richness and presence of species in each replicate.

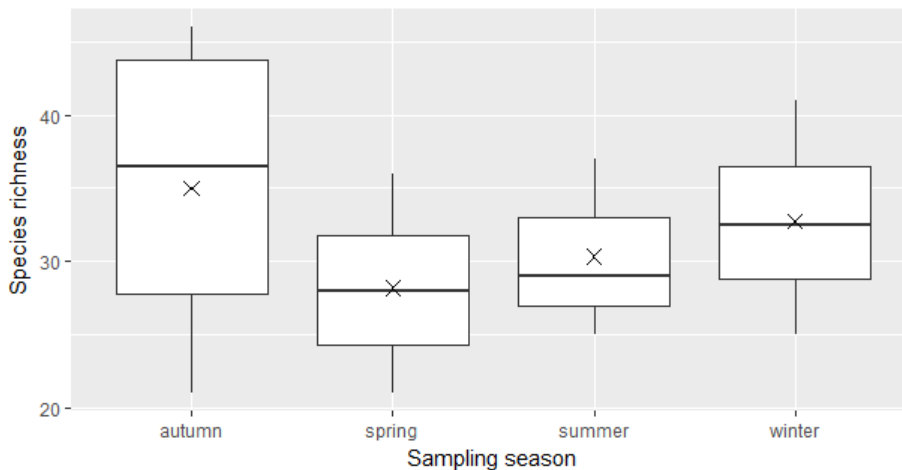
#### 3.4.1 Species richness

Species richness is the total amount of species found in a sample. For all the replicates sampled in this thesis, there was a great variety in species richness (figure 3.8). The highest species richness was found in November (46 species), while the lowest was found in April and October (21 species). Most other replicates had species richness between 25-35 species.



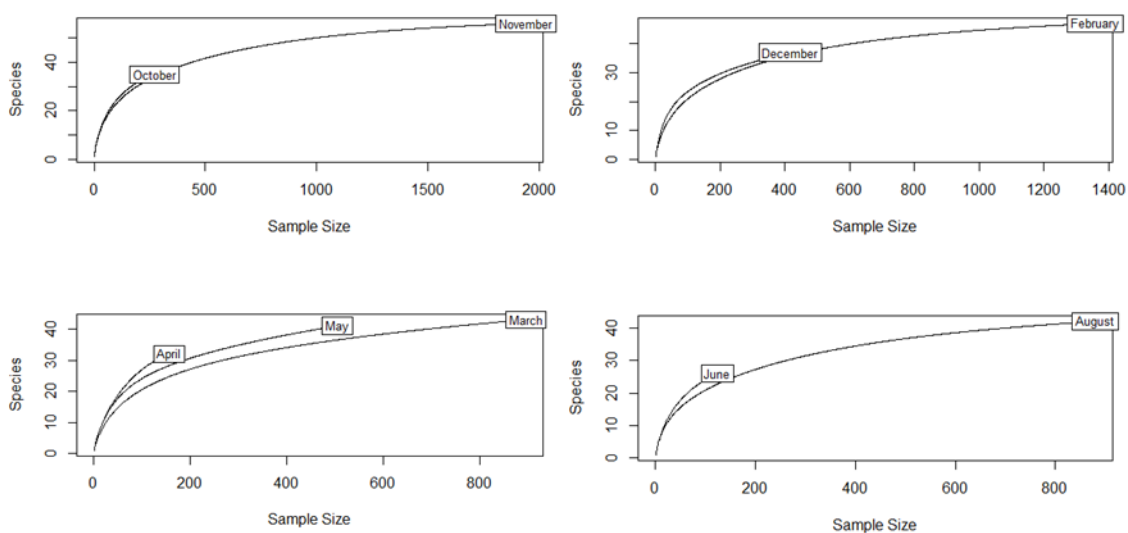
**Figure 3.8:** Species richness is plotted each sampling replicate collected in this study

Autumn showed the highest species richness and the highest mean value for all seasons (figure 3.19). However, the size of the box for this season suggests a high variety in in the values. For spring and summer, the mean value for species richness were lower, but as the boxes are shorter, the values are more in agreement and more similar. Winter had a slightly higher mean value than summer and spring, but there are more outliers, and a slight larger box. Note that summer only had three replicates, one in June and two in August. Other seasons had more replicates and give more certain results. Spring had the most replicates, with a total of six.



**Figure 3.9:** All sampling replicates are divided into seasons and plotted against species richness. The line in the box represents the median and the X represents the mean. Upper and lower whiskers represent upper and lower 25% quartile respectively

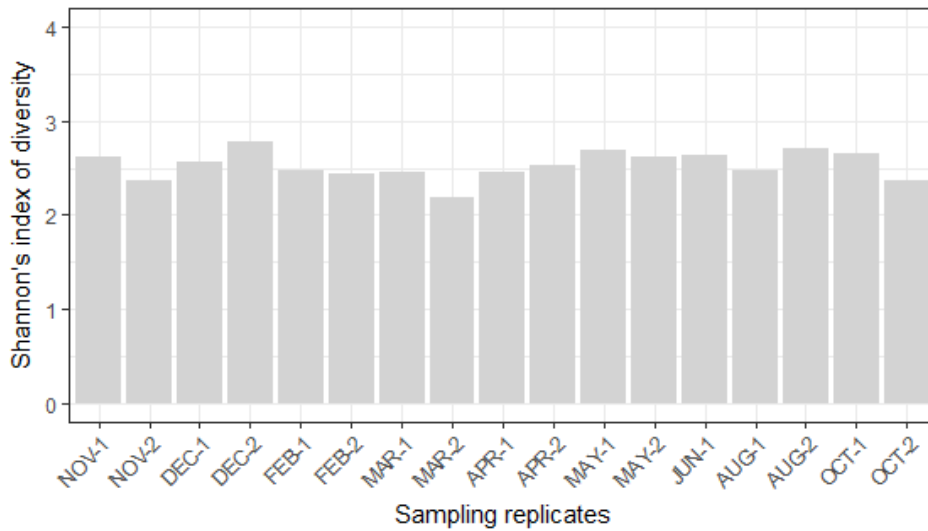
Rarefaction curves were made for each sampling season (figure 3.10). For all curves, species richness is plotted against sample size, showing that more species are found as sampling increases. For autumn, the replicates sampled in November had a total number of species close to 2000. For October, the total number of specimens were only close to 300. However, the sample size for October was relatively smaller than November. For winter, there was a large difference between the two sampled months for specimen abundance. December had around 400 specimens while February has around 1400. The number of species were relatively the same. In spring, the highest number of species and specimens were found in the earliest month, while both numbers decrease closer to summer. March was a particularly large sample, with almost three times as much sediment collected. The difference for the two months in summer are high. However, June only had one sample, and therefore only half of the sampling effort than that of August. Summer and spring showed the lowest number of specimens sampled, while winter showed the lowest abundance of species.



**Figure 3.10:** Rarefaction curves for each sampling season. Number of species are plotted against sample size (abundance). Note the difference in scales on both axes

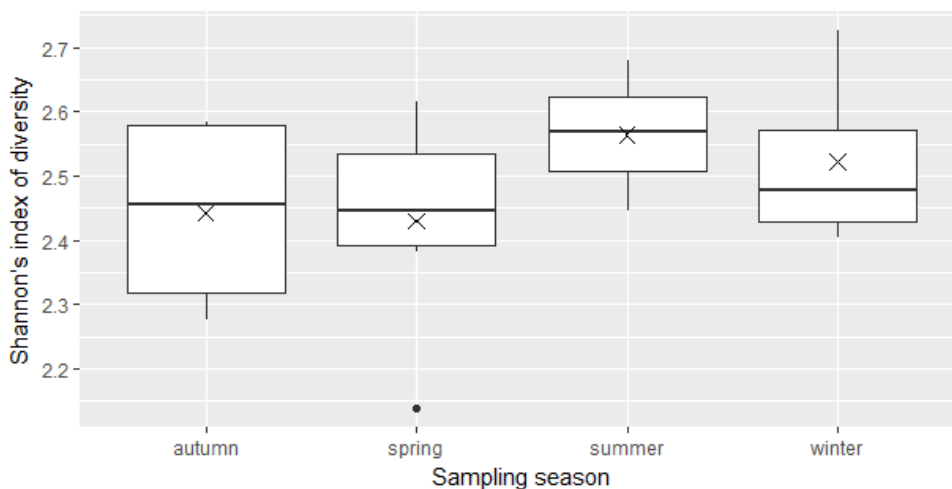
### 3.4.2 Indices of biodiversity

The Shannon Weaver index of diversity for all replicates are quite similar with all replicates showing a value closely to 2.5 (Figure 3.11). Thus, there is a low variation in the index, which gives a low variation in biodiversity between the replicates. The lowest value for this index was found in March with a value of 2.13, and the highest value was found in December with a value of 2.75.



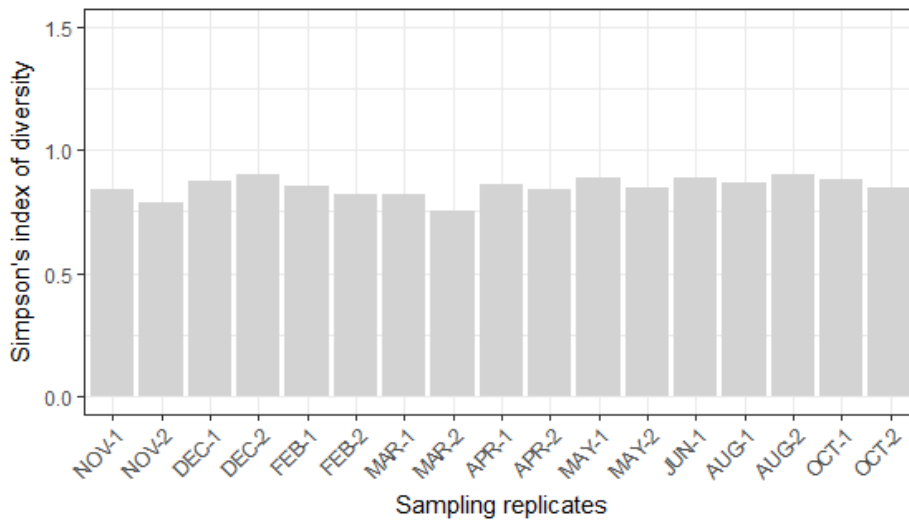
**Figure 3.11:** Shannon Weaver index of diversity is plotted against each sampling replicate collected in this study

Summer had the highest mean value for Shannon Weaver, as well as the most agreeable values showed by a narrow box (figure 3.12). The lowest mean value is found in spring. Autumn shows the most dissimilarity between values. The boxplot shows that there are overall few outliers throughout all seasons with the exception of the upper quartile in winter. Thus, the highest value of the index was found in summer, and the lowest diversity was found in spring. The sampling seasons with the lowest values were all found at an intermediate level of species richness. Summer, which had the highest index value are the sampling with some of the lowest values for species richness (See figure 3.10).



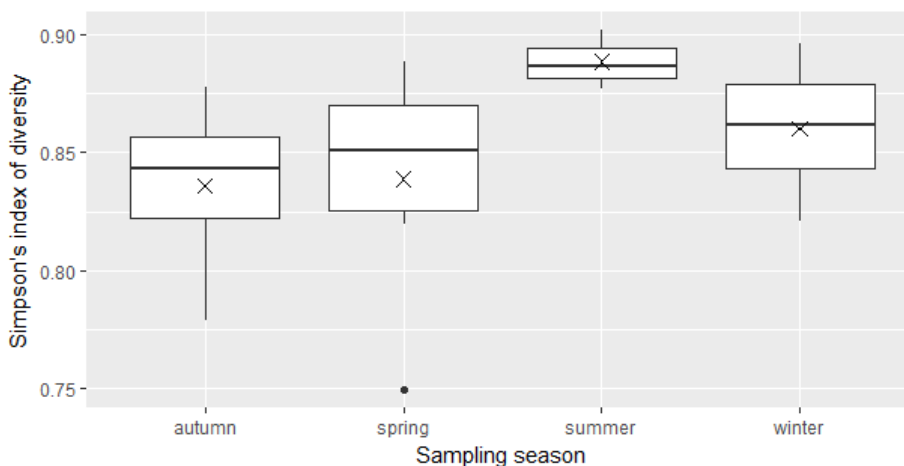
**Figure 3.12:** All sampling replicates are divided into seasons and plotted against Shannon Weaver index of biodiversity. The line in the box represents the median and the X represents the mean. Upper and lower whiskers represent upper and lower 25% quartile respectively

Simpson's index of diversity was measured for each replicate (figure 3.13). There was very little variation in the values throughout the sampling. Most values are around 0.80 to 0.88. The highest value was found in August with a value of 0.90, and the lowest value was found in March with a value of 0.74.



**Figure 3.13:** Simpson index of diversity is plotted against each sampling replicate collected in this study

There was a clear higher mean value for summer than all other seasons (figure 3.14). In addition, there is more agreement between each value calculated for this season. Autumn had the lowest mean value, but there are several outliers. There is little variation in the index, but all replicates show high values for biodiversity.

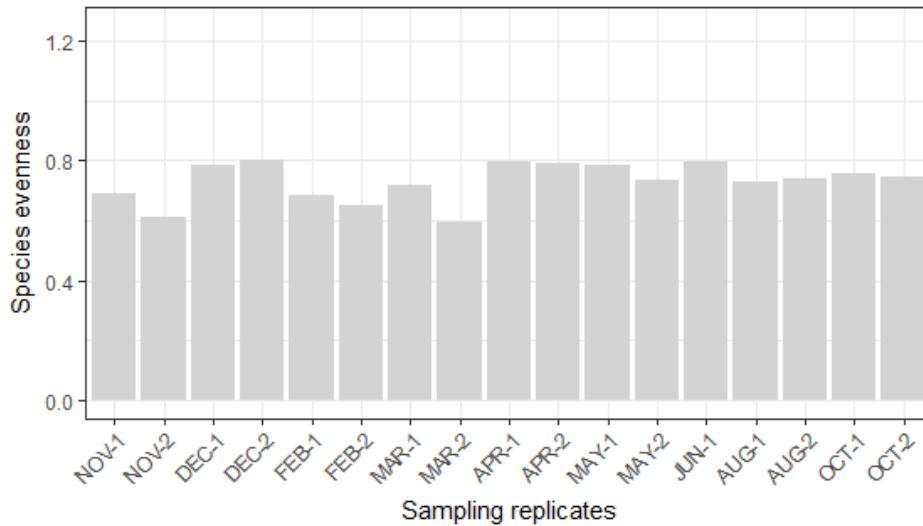


**Figure 3.14:** All sampling replicates are divided into seasons and plotted against Simpson index of biodiversity. The line in the box represents the median and the X represents the mean. Upper and lower whiskers represent upper and lower 25% quartile respectively



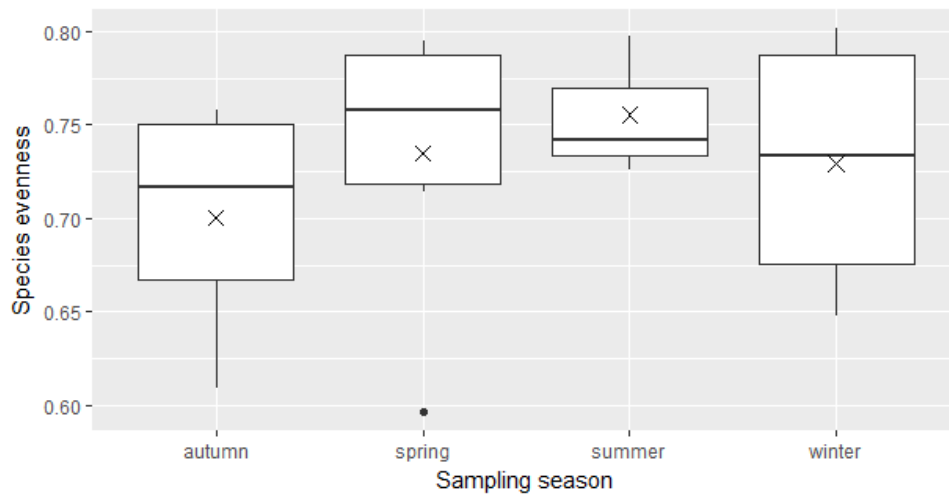
### 3.4.3 Species evenness

The species evenness between the replicates showed some variation (figure 3.15). The lowest species evenness was found in March with a value of 0.59. The highest evenness was found in April and June with a value of 0.79, giving a total change between the highest and lowest value of 0.20.



**Figure 3.15:** Species evenness is plotted against each sampling replicate collected in this study

Summer showed the highest mean value for species evenness, followed by spring and then winter (figure 3.16). Autumn had the lowest species evenness, with a mean value of 0.5 less than summer. Summer also had the highest similarity between the values. Winter had the most dissimilarity between the values. Autumn had more values in the lower quartile, and most values are below the median. The mean value for spring is below the median, showing that the mean value is below the midline of the data. Again, note the differences in sampling effort, with the fewest values in summer and most values in spring.



**Figure 3.16:** All sampling replicates are divided into seasons and plotted against species evenness. The line in the box represents the median and the X represents the mean. Upper and lower whiskers represent upper and lower 25% quartile respectively

### 3.5 Feeding strategies of Amphipoda

A thorough literature search was conducted to investigate the different feeding strategies utilized by the amphipod families found in this study. Table 3.2 shows the feeding strategies exhibited by members of the families identified and the literature that describes them. The species studied by these authors are not necessary the same species found herein, but most of the literature discuss the feeding strategies in terms of families. Buhl-Mortensen (1996) has collected the data from other literature which is reproduced here; Besner (1976), Biernbaum (1979), Chevrier et al. (1991), Enequist (1949) and Sainte-Marie and Brunel (1985).

**Table 3.2:** Feeding strategies utilized by the different families found in this study. Results are collected by conducting a literature search.

Feeding Strategy	Families	Literature
<b>Detritus feeding</b>	Ampeliscidae, Liljeborgiidae, Melphidippidae, Oedicerotidae, Pardaliscidae, Phoxocephalidae, Aoridae, Photidae, Podoceridae, Calliopiidae, Urothoidae	Enequist (1949), Poltermann (2001), Ysebaert et al. (1988)
<b>Feeding on benthos</b>	Epimeriidae, Synopiidae	Klages and Gutt (1990), Buhl-Mortensen (1996), JL Barnard (1972)
<b>Predatory</b>	Eusiridae, Phoxocephalidae, Stegocephalidae	Enequist (1949), Watling (2013)
<b>Selective feeding</b>	Eusiridae	Enequist (1949)
<b>Commensal feeding</b>	Amphilochidae, Epimeriidae, Stenothoidae	Enequist (1949), Buhl-Mortensen (1996), Vader and Krapp-Schickel (1996)
<b>Carnivore</b>	Pardaliscidae, Hyperiididae	Buhl-Mortensen (1996), Auel et al. (2002)
<b>Scavenger</b>	Opisidae, Tryphosidae, Uristidae	Buhl-Mortensen (1996)
<b>Suspension feeder</b>	Eusiridae, Podoceridae, Ischyroceridae	Buhl-Mortensen (1996)
<b>Unknown</b>	Aristiidae, Atylidae, Cyproideidae, Leucothoidae, Pleustidae, Schopelocheiridae, Stilipedidae	

## 4 Discussion

Amphipods are an ecologically important group of benthic invertebrates. This study focused on doing an inventory of the amphipod community at a fixed station in Hjeltefjord throughout a one-year span in order to describe the fauna present. Further, species richness and abundance were investigated to see if there was any possible seasonal variation in the species and the community. In addition, the possible influence of varying sampling effort on the results are discussed. Through the results collected and analysed herein, it is now possible to discuss the objectives presented in this study, and further see if the results could have implications for the improvement of environmental monitoring.

### 4.1 The amphipod-fauna of Hjeltefjord

The morphological identification conducted in this study came with some difficulties. While some families have species that are easily distinguishable, some families have members that are very hard to separate from each other. Families such as Photidae, Ischyroceridae and Stenothoidae have males and females which are sexually dimorphous, meaning that they are morphologically different from one another. Often, the males have more pronounced characters than the females. Most specimens found from these families were females and juveniles. With the less pronounced characters in these specimens that are small and not fully developed, it makes identification of these specimens quite difficult. A variety of literature was used. Much of the literature used herein is written over 100 years ago, which means the material they have based their identification keys on are quite old. Older material is often preserved in 70 % ethanol or formalin, which is different from today where material is mostly preserved in 95 % ethanol. Body color and eye color can change when the specimens are preserved in different media. This further complicates the identification process as these characters sometimes are a part of the identification keys. During the field work, many Ampeliscidae specimens were observed with a clear red eye color and a silver metallic body color. These colors were lost when the specimens were preserved in 96 % ethanol. Many amphipods have long, slender bodies and pereopods, which can make it difficult to sample the specimens without damaging them in any way. This can remove characters that are important for the identification. Hence, there will always be some form of uncertainty around the identification of the samples. However, it has been stressed throughout this process that all specimens with the similar characters have been grouped together. Even if the species name given proves to be wrong for some groups of specimens, the specimens grouped together should be of the same species.

6520 specimens were found throughout the year of sampling. These were identified to 73 different species which represented 29 families. Through a literature search conducted herein, it was shown that these families exhibit a variety of feeding strategies (table 3.2). The feeding strategy of a species is often reflected by the habitat in which the species resides. The habitat sampled in this study is a soft-sediment bottom composed of sand and mud with some organic matter present. The feeding strategies utilized by the species found herein concur with the habitat sampled. Five families (Eusiridae, Opisidae, Pardaliscidae, Tryphospidae and Uristidae) have members that are scavengers, carnivores and predators. Almost half of the families were detritus feeding (Ampeliscidae, Aoridae, Calliopiidae, Epimeriidae, Liljeborgiidae, Melphidippidae, Oedicerotidae, Pardaliscidae, Photidae, Phoxocephalidae, Podoceridae and Synopiidae) or suspension feeders (Eusiridae, Ischyroceridae, Podoceridae). For scavengers, carnivores and predators, seasonality is not a factor that greatly affect their food availability. Natural death of other organisms occurs independent of seasonality, but seasonal factors can increase the food availability (Britton and Morton, 1994). For detritus feeding and suspension feeding organisms, the food availability will be dependent on the downfall of organic matter to the benthos, and therefore dependent on seasonality.

Many species identified in this study were represented with fairly low numbers. The family of Melphidippidae (figure 3.3) had quite high abundance, representing 16 % of all specimens recorded. The species *Melphidippa borealis* had high abundance in all replicates, with a large amount of specimens found in November, February and August. As stated by Enequist (1949), this family is normally found at soft-bottom sediments as it feeds on detritus while standing on the bottom. However, one family was clearly dominant in all replicates. The family of Ampeliscidae made up 48 % of the total abundance of specimens in the samples (figure 3.2). Most of the abundance of Ampeliscidae is due to one species, *Byblis\_CHO\_sp.1*. This species had higher abundance in all samples, with especially many specimens found in the replicates collected in November, February, March and August. This species is represented by 2267 specimens. Following, the species *Ampelisca pusilla* was also quite abundant and present in all samples. 13 species from three different genera were identified. This family is highly species diverse, with a total of 312 species described worldwide, with the majority of species found in the northern hemisphere (Horton et al., 2019, Peart, 2018). Earlier studies show that members of this family are often found at soft-bottom sediments, with a great variety in depth (Bellan-Santini and Dauvin, 1997, Bellan-Santini and Dauvin 1993, Peart, 2018). The Ampeliscids are detritus feeders. Enequist (1949) conducted aquarium experiments on, among others, five of

the Ampeliscidae species found in this study: *Ampelisca anomala*, *A. brevicornis*, *A. gibba*, *A. pusilla* and *Byblis gaimardii*. They were all determined to be detritus-feeders. Ampeliscid amphipods are an ecologically important group of species. Several members of the family can build tubes and can therefore provide habitat for other organisms (Bellan-Santini and Dauvin, 1997, Peart, 2018). Because of their placement in the sediments, living in the uppermost centimeters, they can be used as indicators of a healthy or unhealthy environment, as they have been shown to accumulate heavy metals (Peart, 2018).

Unlike all the other families identified in this study, the family of Hyperiididae is pelagic and lives in the water column. The RP-sled used for the sampling in this thesis would normally have a closing mechanism that is supposed to close the opening of the net when the sled is either being deployed down to the bottom or dragged back up to the research vessel. However, this closing mechanism was not fully functional on the sled used here. This results in pelagic organisms being able to enter the net while it is in the water column. The representation of Hyperiididae was relatively small. A total of 36 specimens from two species were found throughout the sampling period. As these species are pelagic it was difficult to discuss any potential seasonal variation for this family in this area as they could more easily have been moving over a larger area.

#### 4.2 Seasonal variation

As shown in the results, the abiotic environment was investigated to see if there were any significant changes in the temperature, salinity or oxygen saturation that could affect the presence of amphipod species. The depth for the CTD-measurements taken are below 200 meters. At this depth, the physical environment is minimally affected by the changes in the physical factors at the surface of the water. The abiotic factors of the area can be affected by currents that cross the northern sill of the fjord. However, there is little reason to believe that the physical environment can explain any change in the species abundance and seasonality as there was little change in the abiotic factors that could affect the survival and food availability. It is however important to take into account that there were several issues with the measurements of the physical factors in this study. Data are lacking for two of the samplings, and there was missing data in several of the measurements. For a more accurate description of the environment, measurements should have been conducted more often.

As presented earlier, increased food availability will increase the energy uptake by the organism and therefore increase the rate of reproduction. The increase in food which was made available

to the benthos through the algal bloom might be a reasonable explanation for the high species richness and abundance that was found in the November, February and March samples (figure 3.8). Earlier studies have shown that there normally are blooms of algae in March and July/August in Hjeltefjorden and surrounding areas (Lännegren, 1980, Spetland et al., 2007). In 2018, the spring algal bloom was decided to be in the middle of March (Egge, J. pers.comm). At this time, samples taken from connecting waters to Hjeltefjorden showed high density of micro algae. One can assume that 2017 would have an algal bloom at the same time as the year before. High occurrence of micro algae was also present in July 2017 (Algeinformasjon, 2017) in northern Hjeltefjord. After the algal blooms have occurred, the biomass needs to fall down to the benthos. Spetland et al. (2007) showed that the sedimentation rate of carbon per day in Korsfjorden (close to Hjeltefjorden) varied greatly between the months. After the algal bloom in March and July there was an increase in the sedimentation rate for about three months before it again decreased (Wassman, 1991, Spetland et al., 2007). It is therefore likely to assume that it takes approximately three months for the biomass to reach the benthic invertebrates.

The richness and abundance seem to follow the algal blooms with a lag of approximately eight months. If the sedimentation rate of the algae takes approximately three months, which again trigger reproduction with an egg-carrying period of four months or more, it implies that the period with highest abundance should be in the same time period as found in November. The low abundance and richness (but high biodiversity) found in summer agrees with this. The algae might have arrived at the benthos at this time, but there has not been enough time for reproduction to begin, and therefore there was a low abundance and richness during this season. The winter had high values for all variables, which is also in agreement with this explanation. If a second algal bloom occurred in July, then a new period of reproduction might clarify the values found for this season. The large abundance which occurs in November and December is not maintained in spring. One can assume, that if the food availability is no longer as high as when the biomass from the algal bloom reaches the benthos, there might be some mortality in juveniles when the food storage in benthos is not large enough to feed the entire community. Therefore, there might be a larger mortality rate after a period with high reproduction which again causes the decrease in abundance.

Many species found in this study were present in very few of the replicates collected (table 3.1). 29 species were found in one or two replicates only, and they all were represented with a low abundance. There was no specific time of year that most of these specimens were found, and so it is therefore difficult to be able to interpret any form of seasonal variation for these species.

However, 35 species were represented in six replicates or more, with a fair amount of abundance throughout the sampling year (table 3.1, figure 3.7). For these species, there seems to be some parts of the year where most of them have their highest peaks in abundance. Most species had their highest abundance in either February (20 species), November (13 species) or August (6 species). Some species within the same family have their highest abundance at the same time (for example *Monoculodes* sp., *Rostriculodes* sp. and *Oediceropsis brevicornis*, and *Tmetonyx cicada* and *Tmetonyx acutus*, (figure 3.7, appendix C). However, the species only peak in one of the replicates, not both, and the abundance is somewhat different between these. Many of the species show some form of variation throughout the year, but there is no correlation in seasonal variation in the community. One species who did show more certain variation was *Melphidippa borealis*. This species had three peaks in the abundance, November, February and August. The peaks in November and August are quite high, while the peak in February show the greatest abundance. *M. borealis* does not necessarily follow the plausible explanation that the amphipod community follows the downfall of biomass. It might therefore be other factors which are not studied herein that have affected their abundance and variation. The high abundance, however, further strengthens that soft-bottom sediments is a habitat well suited for this family and its feeding strategies.

The study site is shown to be especially suitable for the family Ampeliscidae. This family is highly abundant throughout the year, with all species (apart from 20 specimens of *Byblis\_CHO\_sp.2* found in August and *Byblis longicornis* which has its highest peak in March) peaking in November. As ampeliscids are sediment-dwelling and detritus feeding (Bellan-Santini and Dauvin, 1997, Enequist, 1949), and highly dominant over all other families, the study site seems to be a typical “Ampeliscidae-site”.

There have been several studies on seasonal variation of amphipods from study sites all over the world. However, most studies have focused on one or a few species of amphipods. Nygård et al. (2010) focused on the species *Onisimus litoralis*, where mating occurred in November and release of juveniles was set to spring. Another study conducted by Lindström and Lindström (1980) on the species *Pontoporeia affinis* showed that the species reached sexual maturity between October and December, which would give an increase in abundance after the reproduction period. Werner and Auel (2005) conducted a study of the seasonal variability in abundance of four different species of amphipoda. Three of the species showed no seasonality, while one species, *Apherusa glacialis* had higher abundance in summer. Other studies have focused on the change in the amphipod-fauna between fjords or gradients between fjords and

offshore areas. Some examples of this kind of study are Buhl-Jensen (1986), Buhl-Jensen and Fosså (1991) and Buhl-Mortensen (1996). There seem to very little literature investigating the seasonal changes in the same area. It is therefore difficult to compare the results obtained herein with other literature.

### 4.3 Biological factors vs. sampling effort

As discussed previously, environmental monitoring is often conducted by using quantitative sampling methods. Quantitative methods would make it easier to obtain comparable samples and replicates in a study like the one conducted here. With quantitative sampling one can make sure that the same amount of volume or area are sampled each time. The sampling method used in this thesis is a semi-quantitative method. It is therefore not possible to calculate the specific area sampled. However, during the sampling it was stressed that all the variables such as haul speed, haul length and coordinates for start was approximately the same to be able to have as comparable replicates as possible. The method used herein for sampling of amphipods samples at an acceptable level of replicability for these species (Buhl-Jensen and Fosså 1991), but the sled only samples the top layer of the sediment. This makes it less likely that the amphipods living deeper into the sediments are caught during the sampling (Brattegard and Fosså, 1991). An epibenthic sled is therefore a better method than quantitative gear such as a grab for the assessment of epibenthic fauna. Most species are not distributed uniformly in their habitat. Most species are distributed patchily, or clustered, in an area (Whitman Miller and Ambrose, 2000). It is therefore not given that the sled is hauled over the area where the amphipods are residing, which again will affect the abundance and richness found in the samples.

If the sampling effort is larger, it is most likely that one would encounter more specimens and more species (Gotelli and Colwell, 2001). Rarefaction curves based on the sampling conducted in this study (figure 3.10) show that there is an increase in species when there is an increase in sample size (individuals collected). In this study, the sampling effort varied some between the sampling seasons. Spring had more sampled months than the other seasons, with a total of six replicates, while summer only had three replicates. Autumn and winter both had four replicates. June only had half of the sampling effort compared to the other months. Often there was some variety as to how much sediments that were collected by the sled (table 2.1). The replicates collected in March were particularly big and filled with large amount of sediments. Most other samples had a moderate amount of sediments. The one replicate taken in June was very small and contained almost no sediment at all. In the April sample there was a large occurrence of copepoda in the replicates, which took up a lot of space in the codend. This can affect the



abundance of specimens and which species that are found. Furthermore, it is important to remember that the two months defined as the autumn in this study are sampled from two different years. There is some difference between these two samplings. November 2017 had very high species richness and a large abundance (1937 specimens), while October 2018 had a very low abundance (269 specimens) and a considerably lower value for species richness. These differences in sampling size is reflected in the rarefaction curves.

If one is to assume that the size of the samples is positively correlated with abundance and richness of species found, then the highest values for these variables should be found in March as this sampling had a much larger portion of sediments than the other samples. In addition, one should expect that a larger sediment sample would increase the presence of sediment-dwelling amphipods, such as ampeliscids, which is the most dominant group found in this study. This is, however, not always true for the results found in this study. The largest amount of ampeliscids are found in November, which had a moderate amount of sediments. One of the replicates in March had a high abundance of *Byblis\_CHO\_sp.1*, but this was still less than found in a single replicate in November, which has, in total, twice the abundance for this species. *Melphidippa borealis* also had a higher abundance in November, and most other species either have a slightly higher abundance in November, or the abundance is approximately the same for these two months. The species richness is higher in November as well, with ten more species present. Some correlation between sample size and abundance and richness is present, but the amount of sediment sampled does not seem to be a decisive factor for being able to sample a large number of sediment-dwelling amphipods.

An important thing is to consider then, is whether the results in this study are affected more by the actual biological factors that would determine when species are present throughout the year, or if it is more affected by the variety in sampling effort. Taking all into account, it is believed that the variation in species richness and abundance found in the autumn and winter are decided by biological factors such as algal blooms providing favorable conditions for the amphipods residing in the area. However, the sampling effort could have affected the data to some extent as there is a bias in number of replicates and sample size.

#### 4.4 Conclusion and implications for further studies

A great diversity of species was found at the sampling site. The area seems to be especially suited for Ampeliscid amphipods, as these dominated the abundance throughout the year. Many species had low presence and abundance, while others were present in large numbers. This

makes it difficult to investigate any possible seasonal variation. The period with most species richness, species evenness and high values for biodiversity indices seem to be a result of the spring algal bloom, but this is however not true for all species. Other factors that was not tested here might also have an effect on the presence or absence of species. The differences in sample size did not seem to affect the sampling greatly, as larger samples did not produce a higher abundance or diversity of species. However, the low values for these measurements in summer could be a result of a lower sampling effort in this season compared to the others.

Sampling for environmental monitoring should be conducted in periods with high richness and abundance which would be in November according to this thesis. Spring and summer seem to be the best seasons to sample if one is interested in a community with high evenness, but sampling for high species richness should be conducted in autumn or winter. In addition, one should sample when Ampeliscid amphipods have high presence as these are used as indicators for the state of the environment. More research is needed to give a better understanding as to if there is seasonal variation in an amphipod community. For more certain results, samples should have been collected over several years with samplings each month. There should be more replicates each month and the samples should be collected at approximately the same time each month. In this study it was not possible to collect data to this extent due to limits of time and resources. If one is to improve environmental monitoring of amphipods, the sampling should be standardized as much as possible.

## 5 References

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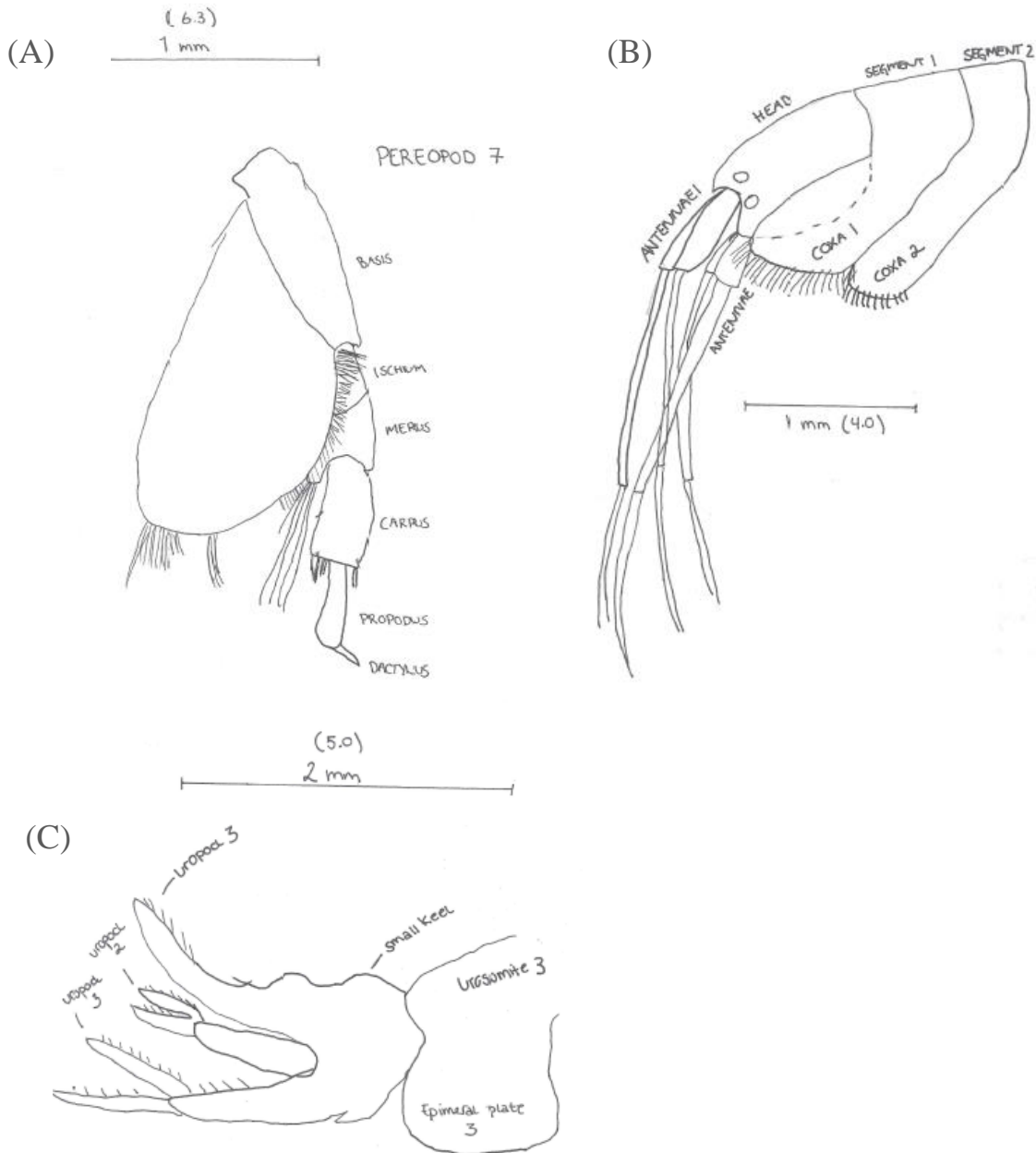


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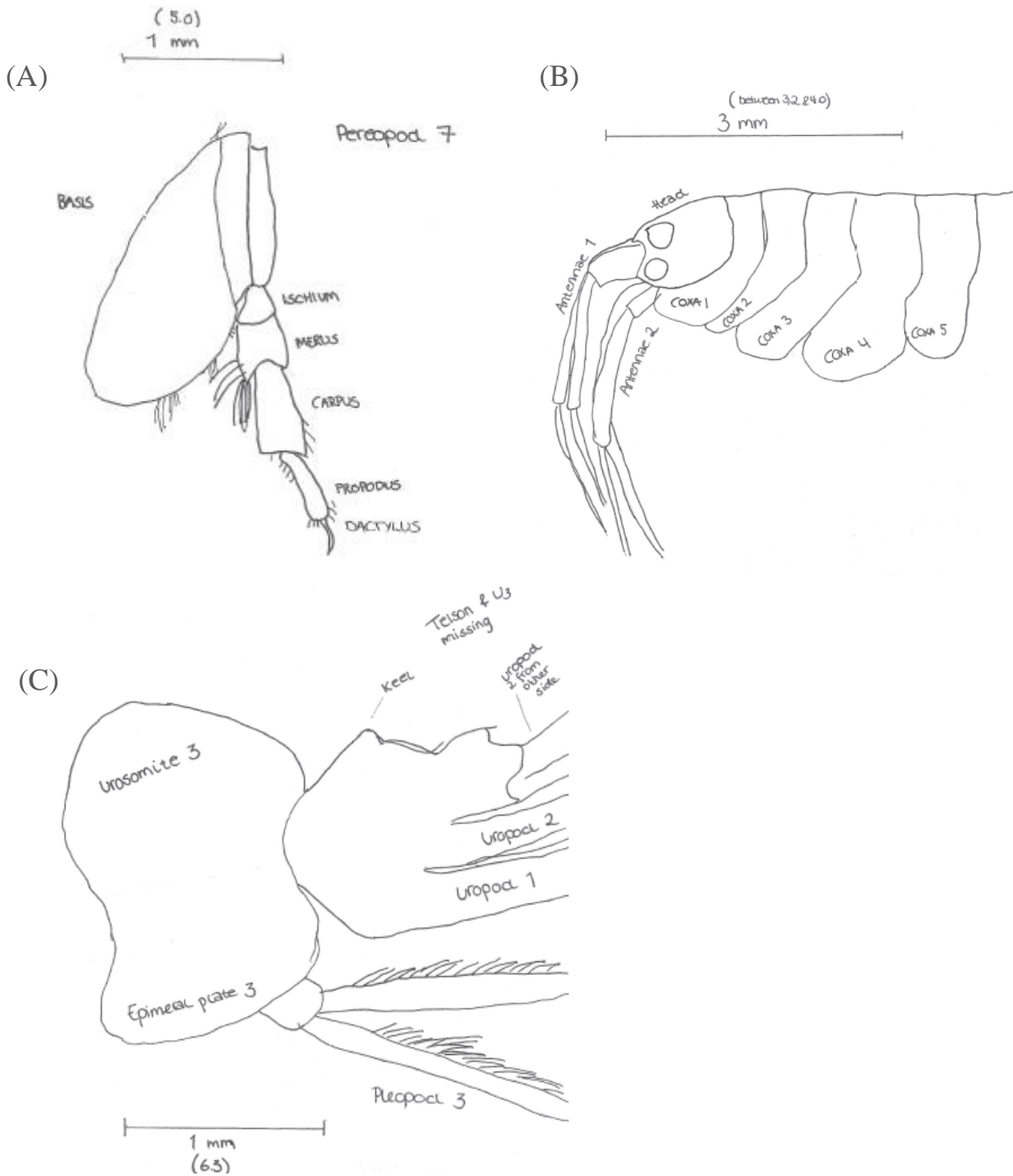
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## 6 Appendices

### Appendix A - Illustrations of unidentified *Byblis* specimens



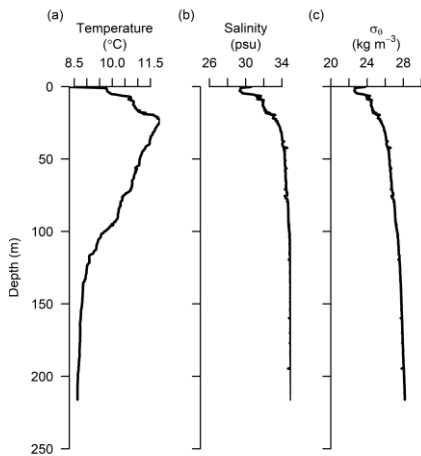
**Figure A1:** Illustrations showing unidentified specimen of the genus *Byblis*, named *Byblis\_CHO\_sp.1*. The specimen illustrated here was collected in the decant from the second replicate taken in August. The total length of the specimen was 9 mm. (A): Pereopod 7 showing placement of setae and all six joints of the pereopod. (B): Head with antennae and the two first segments of the mesosome. (C): Appendages of the urosome and the last urosomite/epimeral plate. Illustrations: C. Østensvig 27.11.18. Pencil drawing through dissecting microscope with a side mounted drawing tube. Enhanced with manual inking.



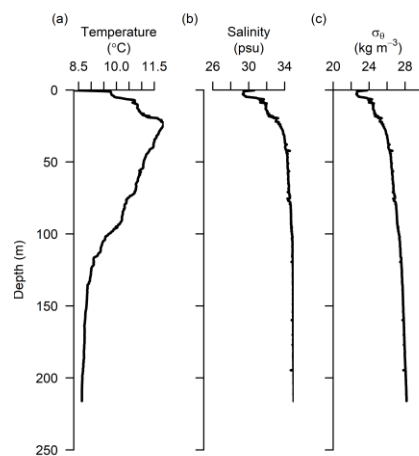
**Figure A2:** Illustrations showing unidentified specimen of the genus *Byblis*, named *Byblis\_CHO\_sp.2*. The specimen illustrated here was collected in the decant from the second replicate taken in August. The total length of the specimen was 10 mm. (A) Pereopod 7 showing placement of setae and all six joints of the pereopod. (B): Head with antennae and the first five segments of the mesosome. (C): Appendages of the urosome and the last urosomite/epimeral plate. Illustrations: C. Østenvig 26.11.18. Pencil drawing through dissecting microscope with a side mounted drawing tube. Enhanced with manual inking.

## Appendix B - Environmental data

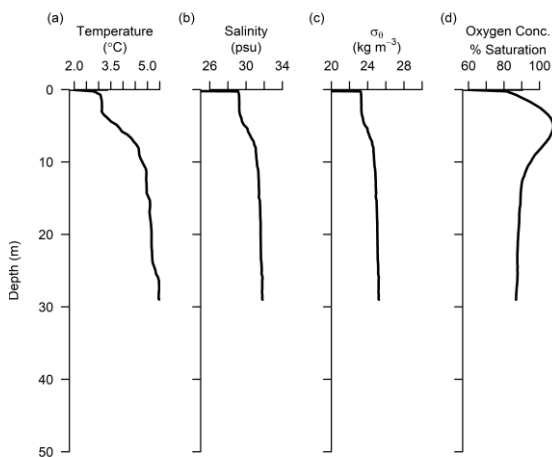
The following graphs show CTD profiles for the samples from November to August. Temperature, salinity and density was measured at all samplings. Oxygen was measured from March to August.



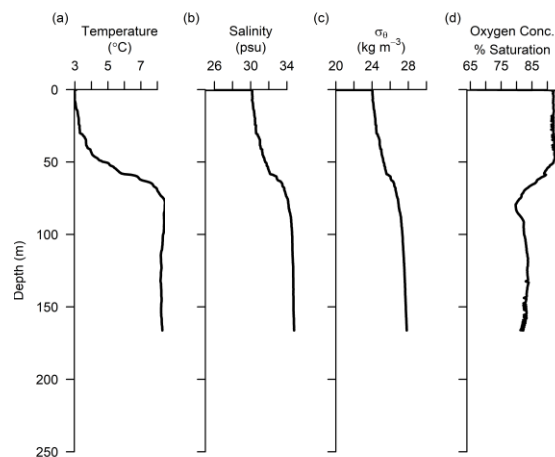
**Figure B1:** CTD profile for November (HB-2017-11-13). Environmental factors are plotted against depth. Note the lack of data for dissolved oxygen (%).



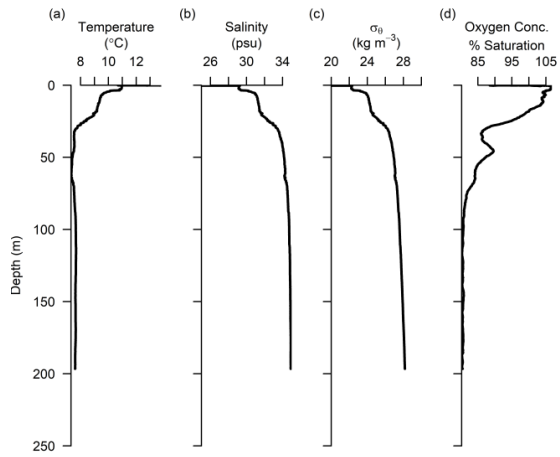
**Figure B2:** CTD profile for February (HB-2018-02-19). Environmental factors are plotted against depth. Note the lack of data for dissolved oxygen (%).



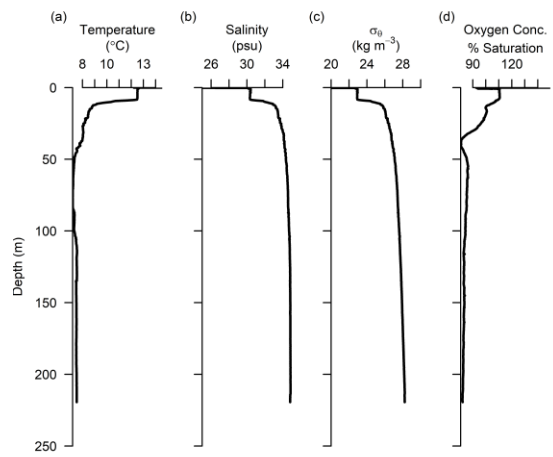
**Figure B3:** CTD profile for March (HB-2018-03-10). Environmental factors are plotted against depth. Note that depth stops at 30 meters due to a fault in the CTD-measurement.



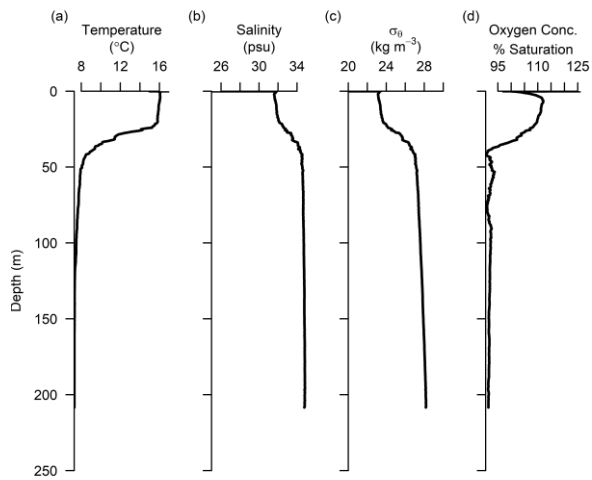
**Figure B4:** CTD profile for April (HB-2018-04-05). Environmental factors are plotted against depth.



**Figure B5:** CTD profile for May (HB-2018-05-23). Environmental factors are plotted against depth.



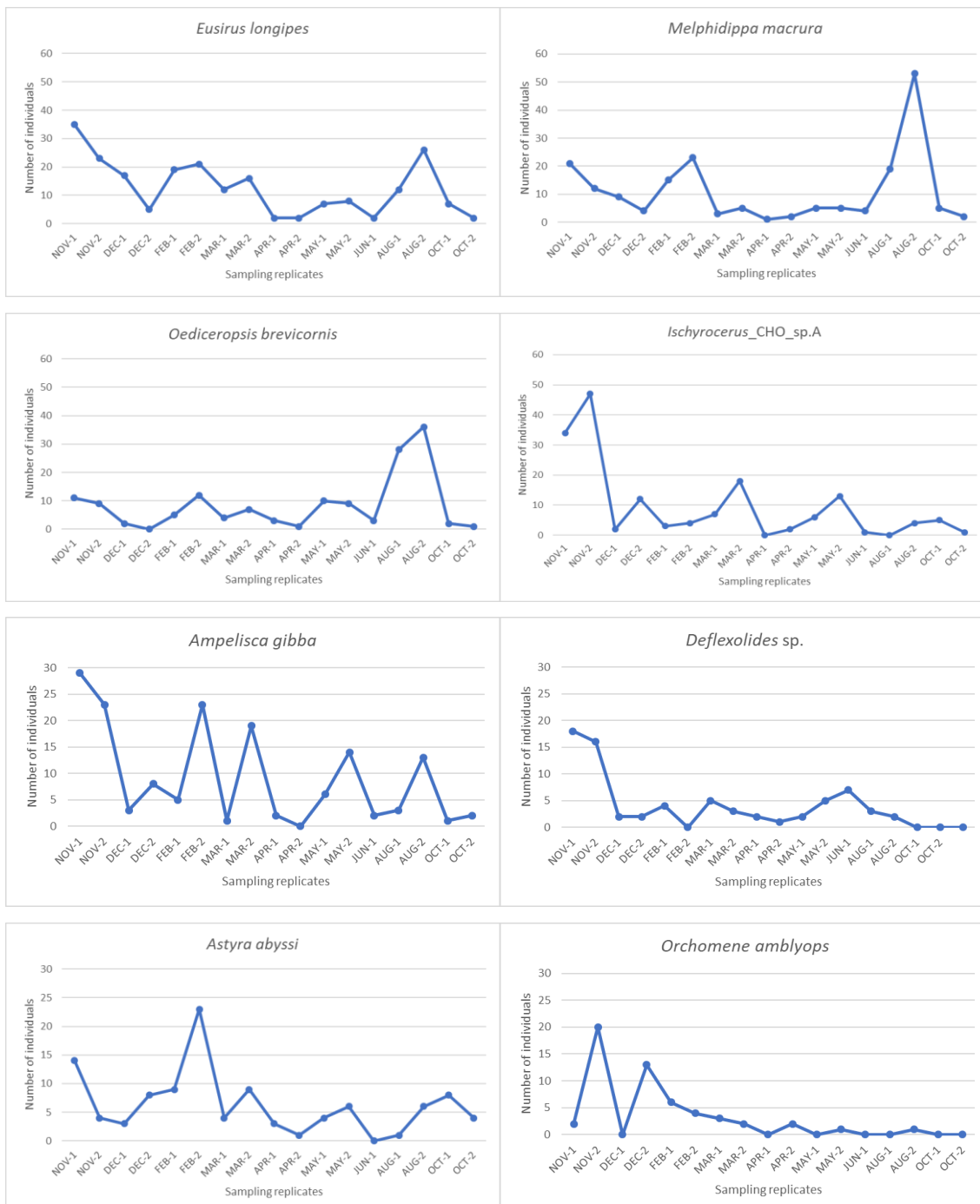
**Figure B6:** CTD profile for June (HB-2018-06-08). Environmental factors are Plotted against depth.

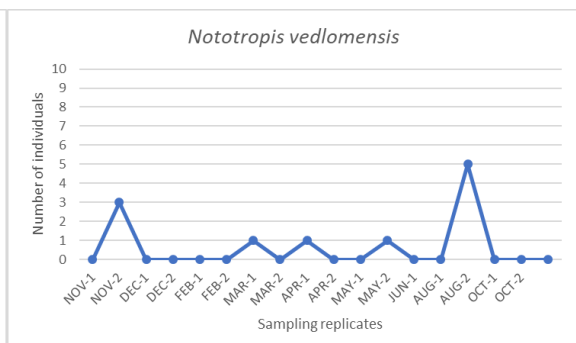
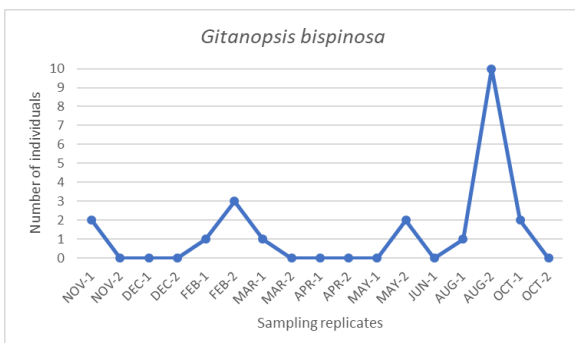
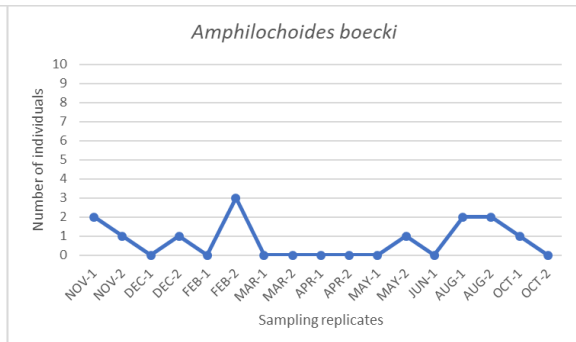
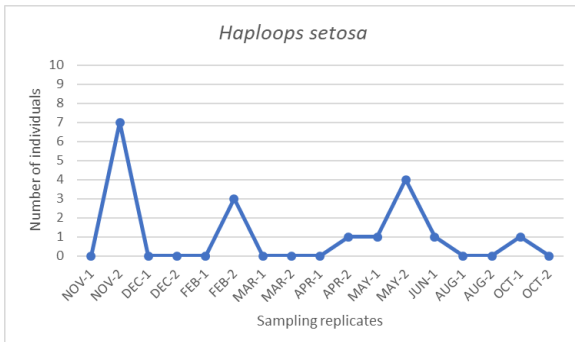
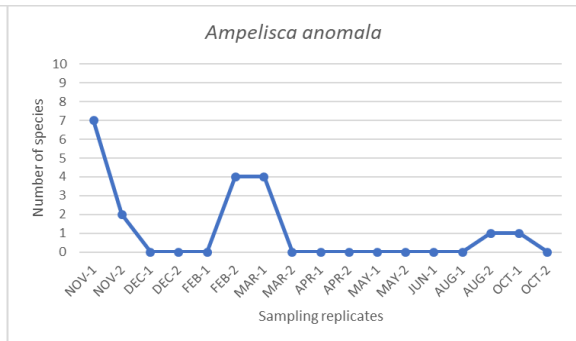
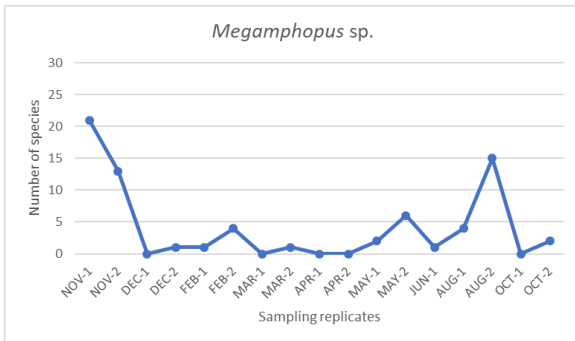
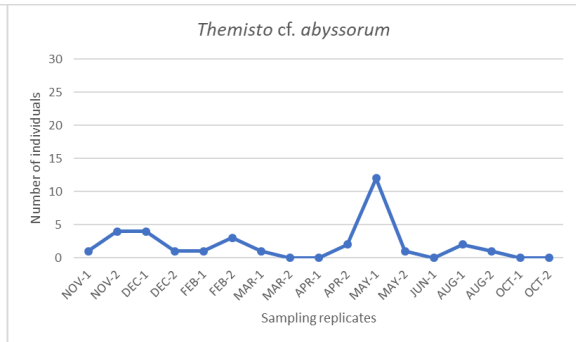
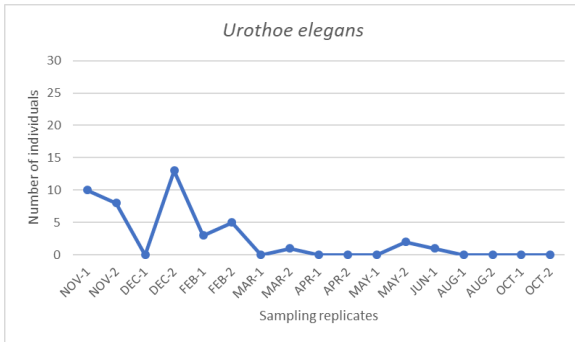
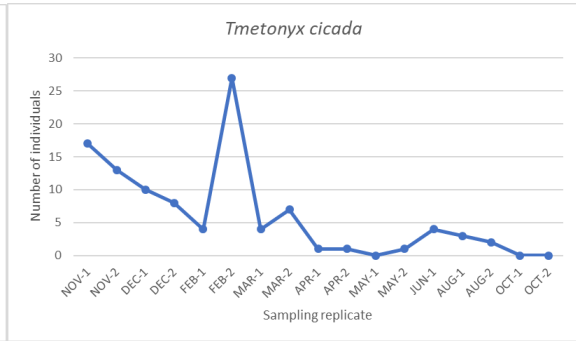
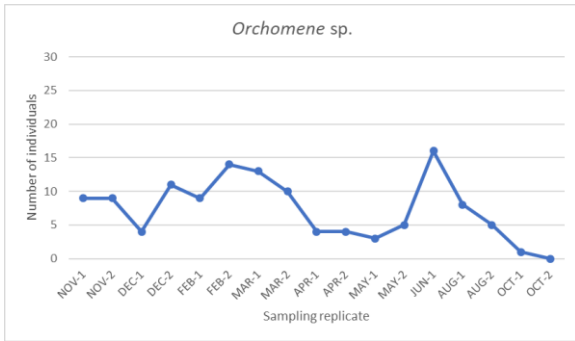


**Figure B7:** CTD profile for August (HB-2018-08-11). Environmental factors are plotted against depth.

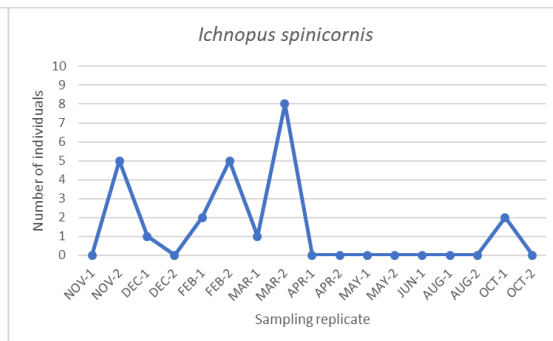
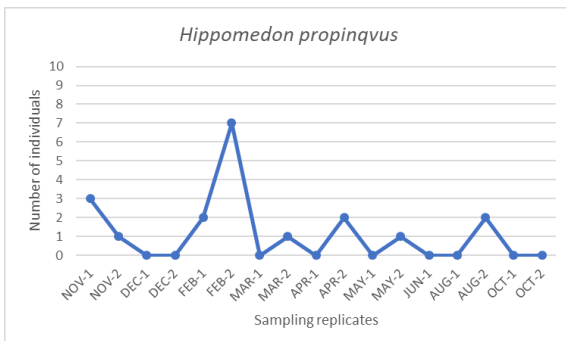
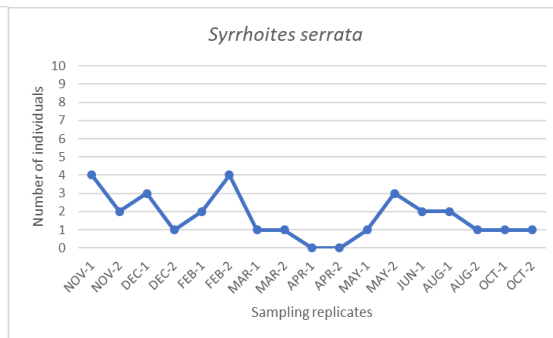
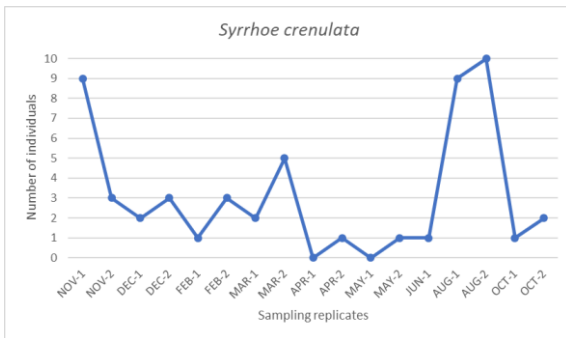
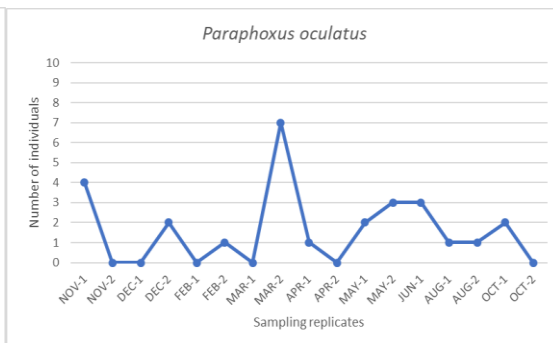
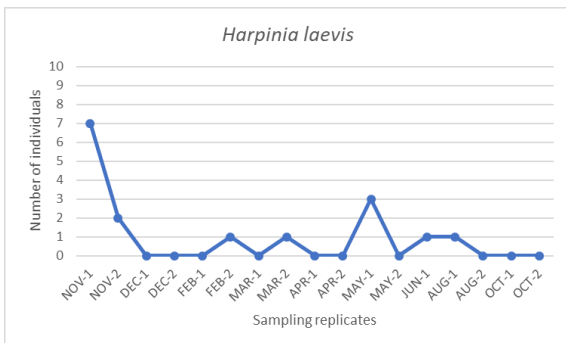
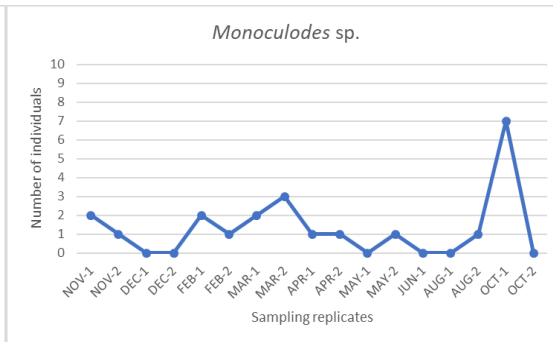
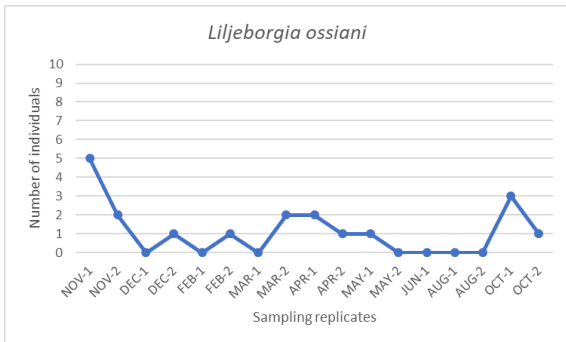
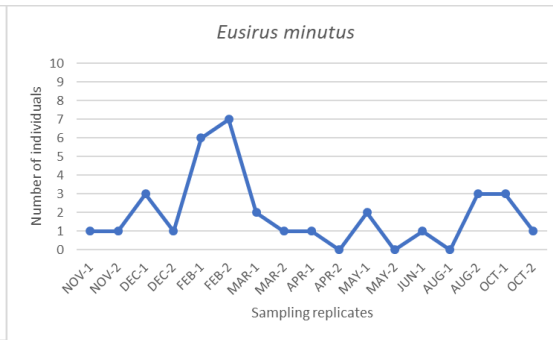
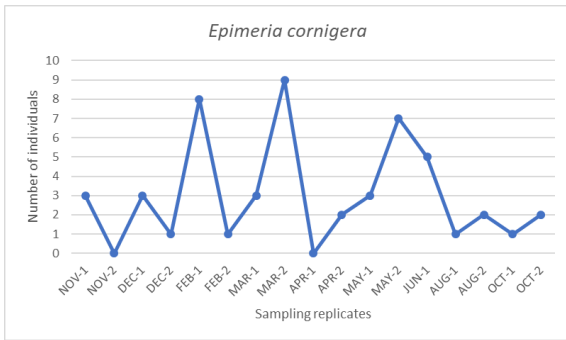
## Appendix C – Variation in species abundance

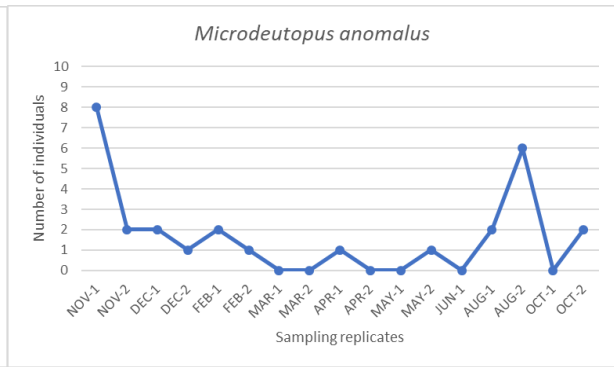
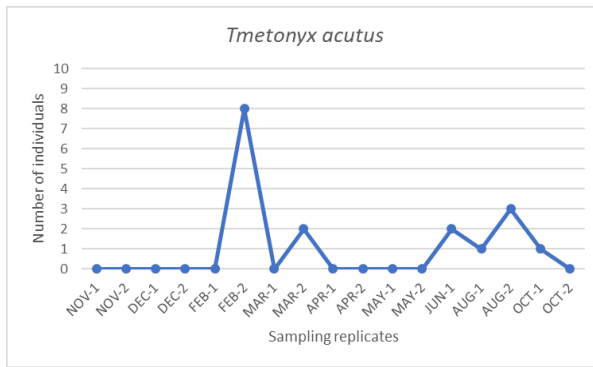
The following figures show the variation in abundance for a selection of the species identified in this study. These are all species that were represented with at least 10 specimens and were present in at least five replicates throughout the year. Species are arranged in an order from highest to lowest abundance. Note the difference in the y-axis. All y-axes have been standardized to having the highest value as either 60, 30 or 10 specimens.











## Appendix D - Biodiversity

*Table D1: Shows an overview over biodiversity calculations for each replicate sampled in this study*

<b>Sampling replicate</b>	<b>Species richness</b>	<b>Shannon Weaver index of diversity</b>	<b>Simpson's index of diversity</b>	<b>Species evenness</b>
HB-2017-11-13-1	43	2.5832	0.8369	0.6868
HB-2017-11-13-2	46	2.3319	0.7788	0.6090
HB-2017-12-13-1	25	2.5178	0.8729	0.7822
HB-2017-12-13-2	30	2.7266	0.8965	0.8017
HB-2018-02-19-1	35	2.4367	0.8504	0.6854
HB-2018-02-19-2	41	2.4044	0.8211	0.6475
HB-2018-03-10-1	28	2.3810	0.8195	0.7146
HB-2018-03-10-2	36	2.137	0.7493	0.5964
HB-2018-04-05-1	21	2.4208	0.8739	0.7951
HB-2018-04-05-2	23	2.4708	0.8582	0.7880
HB-2018-05-23-1	28	2.6149	0.8887	0.7847
HB-2018-05-23-2	33	2.5568	0.8442	0.7313
HB-2018-06-08-1	25	2.5678	0.8866	0.7977
HB-2018-08-11-1	29	2.4449	0.8770	0.7261
HB-2018-08-11-2	37	2.6790	0.9021	0.7419
HB-2018-10-19-1	30	2.5783	0.8780	0.7581
HB-2018-10-19-2	21	2.2760	0.8500	0.7476