Seasonal zooplankton community patterns along a gradient from land to sea in Isfjorden, Svalbard

Emilie Hernes Vereide

Master thesis in marine biology

Department of Biosciences
Section for Aquatic Biology and Toxicology

UNIVERSITY OF OSLO

December 2019

Seasonal zooplankton community patterns along a gradient from land to sea in Isfjorden, Svalbard

Emilie Hernes Vereide
emilievereide@gmail.com
+4794174340

Supervisors:

Dag O. Hessen
d.o.hessen@mn.uio.no

Eva Leu
eva.leu@akvaplan.niva.no

Janne Søreide
janne.soreide@unis.no

Acknowledgements

The work presented in the following master thesis was conducted at the Department of Biosciences at the University of Oslo (UiO) and the Department of Arctic Biology at The University Centre in Svalbard (UNIS). The work was carried out with help from my main supervisor Dag O. Hessen (UiO), and my co-supervisors Eva Leu (Akvaplan-NIVA) and Janne Søreide (UNIS).

First of all, I would like to thank my supervisors for their excellent support and feedback. You have all contributed with your much valuable knowledge and support during fieldwork, laboratory work, and writing, in particular. I am so very grateful for your understanding and patience.

I would like to thank the logistics staff at UNIS for boats and helping out in the field, in addition to the crew at R/V Helmer Hanssen. Additionally, I want to thank the crew at R/V Clione for excellent help out in the field. Without you, I would still be stuck in the quicksand at a beach in Svalbard. I would also like to thank the amazing group of people that have helped during fieldwork: Eirik, Sverre, Connor, Nathalie, Emelie, Maeve, Amanda, Charlotte, Paul, Guttorm, Hannah, Anne, and Pernilla. Without you, I would never have had all my zooplankton, nonetheless a thesis. You also contributed to making fieldwork in the Arctic my favorite thing in the world. This master project was a part of the TerrACE project, and I would, therefore, like to thank The Research Council in Norway for funding of the project. Furthermore, I would like to thank Miriam Marquardt for analyzing the chlorophyll at UNIS, and Rune Halvorsen for help with the ordination methods. Also, Slawomir Kwasniweski for help with the identification of zooplankton; without you, I would still be looking into the microscope.

Then, I would like to thank Amanda Poste. I am forever grateful I contacted you two and a half years ago and asked to join TerrACE. You have given me feedback and suggestions from the beginning, and you have been supportive all the way. Despite not being my supervisor, you have given me so much of your valuable time, which has helped me until the very last day.

And of course, I would like to thank Maeve McGovern. Thank you, Maeve, for all the planning of fieldwork, the long days out in the field, the long days in the laboratory, for all help with data

treatment and writing, for the support. Thank you for believing in me when I did not. You have been an inspiration from the first day I met you, and so much of this thesis is due to you.

I would like to thank all the people at AQUA and on the 4th floor. Thank you for the endless cups of coffee, talks, and moments of sharing frustration and joy - also, a huge thanks to Jonas for proofreading. I am glad I tricked you into reading the thesis with your sharp teacher-way of seeing things. Finally, I would like to thank my friends and family. An immense thanks to my family for Sunday dinners and keeping me fed. Without you, I would eat knekkebrød every day. Also, the biggest thank you to all my friends, who in some way kept me sane all this time. Especially, my person in times of need, Selma, and Ole, who bared with me the past months.

Abstract

The retreat of glaciers, melting of permafrost, and increased riverine runoff influence Arctic fjords and their physical and biological environment, but to which extent is poorly known. In this study, I determined the impact of glacial and riverine inputs on the Arctic zooplankton community composition in the largest fjord system in Svalbard, Isfjorden, at 78°North. The physical (temperature, salinity, turbidity, Secchi depth) and biological (chlorophyll *a*) environment were carefully studied seasonally and spatially from the start to the outer end of the three fjord arms of Isfjorden: Billefjorden, Tempelfjorden, and Adventfjorden in May, June and August 2018. The most prominent spatial and seasonal pattern across all fjords was the high contribution of meroplankton to the total zooplankton community. High total (~14.000 ind. m^{-3}) and relative abundance (>50%) of meroplankton were documented at the innermost sites in May, which decreased along the salinity gradient from inner to outer. Meroplankton also showed a clear seasonal shift from cirriped nauplii and cypris in May and June, to bivalve veliger in August. Holoplankton shifted from copepodite stages and adult larger sized copepods, *Calanus* spp. in particular, in May and June, to a dominance of the smaller cyclopoid copepod *Oithona similis* in August. In addition, copepod nauplii dominated at the innermost sites in May relative to the total holoplankton (~70%) and decreased along the salinity gradient from inner to the outer fjord. The trophic modes of zooplankton did not show any clear spatial pattern but shifted seasonally from predominantly herbivores in May to omnivores to August. The zooplankton biomass did not show any significant differences between the months, nor the habitats. However, the species diversity increased from inner to outer in all three months, presumably affected by environmental stress at the innermost sites. By implementation of ordination methods, seasonality was identified as the most important driver of the zooplankton communities, where temperature, salinity, and light availability was shown to explain the most variation. The study also supported that terrestrial input has an impact on the zooplankton communities, in accordance with previous research. The study of zooplankton in coastal areas helps to understand the undergoing changes in these ecosystems. In order to gain more knowledge on future changes in the Arctic, future studies highlighting these subjects are recommended.

Table of contents

1. Introduction

1.1 Arctic fjords in change

Land to sea interactions

Coastal areas are shaped by different terrestrial and freshwater sources such as melting permafrost, rivers, or glaciers. Riverine inputs thus bridge terrestrial and marine ecosystems (Carmack, Winsor, and Williams 2015; Arimitsu, Piatt, and Mueter 2016). Riverine run-off, as well as permafrost thaw, can cause higher turbidity and increased levels of colored dissolved organic matter (DOM) and thus poorer light conditions, but also increased supply of nutrients (Carmack, Winsor, and Williams 2015). In regions where glaciers cover coastal landmasses, this interaction between land and sea can also be influenced by glacial input, which will differ depending on whether glaciers end on land or in the sea (Meire et al. 2017; Hopwood et al. 2019). Melting of glaciers causes freshwater and nutrient input, but also often a heavy load of clay particles promoting turbidity and light attenuation (Forwick et al. 2010; Calleja et al. 2017). It has also been suggested that marine-terminating glaciers influence the hydrography, e.g. by impacting the upwelling of nutrient-rich water (Meire et al. 2017; Hopwood et al. 2019).

As a consequence of nutrient input from land, such as silicate and iron, primary production is often found to be high in coastal areas (Cloern, Foster, and Kleckner 2014; Cape et al. 2019). This may also increase productivity in typically low productive areas due to the advection of high-nutrient water masses (Grebmeier et al. 2006). Similarly, glacial influence, such as direct nutrient input and impact the from upwelling of nutrient-rich water, has been shown to enhance primary production (Calleja et al. 2017; Meire et al. 2017).

Climate change in the Arctic: Implications for the land-sea interactions

The Arctic is particularly impacted by climate change, warming twice as fast as the global average (Overland et al. 2019). Increased temperatures will subsequently lead to stronger near-surface permafrost thaw in coastal areas and increased glacier melt, which in turn increases riverine input and sediment transport (Adakudlu et al. 2019; McGovern et al. 2019). These changes impact the physical and biological environmental factors (Svendsen et al. 2002; Węsławski et al. 2017). The disappearance of coastal sea ice will enhance the primary production, as well as the productive season, which will be prolonged (Kahru et al. 2016).

Even though primary production may be favored by an increase of meltwater induced nutrients (Juul-Pedersen et al. 2015; Arendt et al. 2016), there are contrasting views on this, and studies report adverse effects for a number of reasons (Li et al. 2009; Holding et al. 2019). For example, higher turbidity in coastal areas may decrease the primary production due to less light penetrating the water column (Carmack, Winsor, and Williams 2015). Environmental changes due to glacial and riverine run-off have shown to explain the variation in phytoplankton abundance (Arimitsu, Piatt, and Mueter 2016) and promote smaller cells in favor of large cells (Li et al. 2009; Middelbo et al. 2018).

These changes have potentially contradictory implications for ecosystems in these nearshore regions. Pronounced small scale heterogeneity, in addition to difficulties with accessibility of these high-Arctic coastal environments, leaves them greatly understudied to date. More knowledge is, thus, needed to determine the terrestrial impact on Arctic coastal ecosystems.

1.2 Zooplankton in Arctic fjords

Zooplankton are the prime secondary producers and thus comprise the key trophic link between primary producers and higher trophic levels in marine ecosystems (Kaiser et al. 2011; Slagstad, Ellingsen, and Wassmann 2011). Zooplankton were originally defined as passively drifting organisms with no ability to swim or move actively (Hensen 1887). Many zooplankton species are, however, capable of regulating their bouyancy and thus their vertical position, in addition to drifting with water masses (Munk, Nielsen, and Hansen 2014). Vertical migration makes them able to optimize their food uptake in the water column and minimize their risk of predation (Hays 2003; Pearre 2003). Zooplankton includes a large and diverse group of organisms, varying in size, commonly divided into pico- and microzooplankton (20-200 µm), mesozooplankton (0.2 µm -20 mm), and megazooplankton (>200 mm). In addition to a wide range of size classes, zooplankton includes several taxonomic and functional groups (Kaiser et al. 2011).

Arctic zooplankton comprises more than 170 species of metazoan zooplankton (Kosobokova, Hopcroft, and Hirche 2011). In the Arctic Ocean, crustaceans are highest in species number, where copepods are the most diverse group represented by more than 50% of all Arctic zooplankton species, as well as dominating in terms of biomass and abundance (Sirenko 2001). The strong seasonality at high latitudes in terms of light, ice cover, and thus

the narrow window of primary production influences the abundance and succession of Arctic zooplankton (Søreide et al. 2010; Leu et al. 2011).

Calanus spp. are regarded to be a key species in the Arctic pelagic lipid-based food web (Falk-Petersen, Hopkins, and Sargent 1990). Their life cycle and reproduction are timed to the algal food availability (Søreide et al. 2010). In spring, nauplii and overwintering adults ascend from the deeper water layers, whereas more developed copepodite stages dominate later in the summer and fall (Daase et al. 2013). Several studies also highlight the importance of small copepods, such as *Oithona similis, Pseudocalanus* spp. or *Microcalanus* spp., and suggest that they tend to be overlooked in the marine ecosystem, but are equally important as larger species (Blachowiak-Samolyk et al. 2007; Svensen et al. 2011; Arendt et al. 2016). Following the descend of the larger seasonal migratory copepods in late summer/autumn, smaller copepod species becomes important (Svensen et al. 2011). Pelagic larvae of benthic organisms, meroplankton, enters the plankton only during certain life stages, in contrast to holoplankton, that inhabit the pelagic environment their entire life cycle (Stübner 2016). Meroplankton are also an essential part of the Arctic zooplankton community (Stübner et al. 2016). Meroplankton are mainly present during the peak primary production window, being positively correlated with phytoplankton biomass and temperature (Michelsen et al. 2017). Studies from Adventfjorden, Svalbard, show that meroplankton dominates the zooplankton community both in terms of biomass and abundance throughout the productive season (Stübner 2016).

Zooplankton drivers

In addition to strong seasonality, the zooplankton variability in the Arctic ocean is linked to water mass distribution, circulation (Auel and Hagen 2002; Daase and Eiane 2007; Estrada et al. 2012), and advection (Wassmann et al. 2015). Subsequently, abiotic and biological changes in the environment will influence the zooplankton abundance and distribution, such as temperature and salinity (Daase and Eiane 2007; Kwasniewski et al. 2010; Trudnowska et al. 2015). Variations in the zooplankton community can also be explained by factors related to terrestrial and freshwater input, e.g. changes in the coastal environment (Swalethorp et al. 2014; Arimitsu, Piatt, and Mueter 2016; Middelbo et al. 2018). However, a complete understanding of the influences of terrestrial input is still missing.

Studies from Arctic fjords in Greenland show that the spatial distribution of zooplankton changes substantially along a salinity gradient, from glacial influenced to more open water (Arendt et al. 2016; Middelbo et al. 2018). An increase in the proportion of omnivorous, smaller zooplankton species was seen with higher freshwater impact, with a distinct change in species

composition along the salinity gradient. In more brackish water close to the glaciers, *Microcalanus* spp. and *Pseuodcalanus* spp. were found to dominate, whereas herbivorous, larger copepods such as *Calanus* spp. dominated further out. Additionally, zooplankton may be found in high concentrations in a water layer near the bottom of glacial plumes caused by the system of currents. These areas are subsequently important feeding areas for sea birds and marine mammals (Lydersen et al. 2014). In similarity with glacial impact, Estrada et al. 2012 (Estrada et al. 2012) suggested that increased riverine input will promote a shift from larger to smaller species, as a result of warmer water and increased stratification. Both rotifers and small omnivorous copepods (*Microsetella* spp*., Pseudocalanus* spp*.,* and *Oithona* spp*.)* have also been documented to de dominant closer to the estuaries (Chen, Liu, and Chen 2017). Furthermore, it is hypothesized that increased freshwater input will have a negative impact on oceanic species, but favor resident self-sustaining species (Tang et al. 2011). Higher turbidity may also impact the predator-prey interactions in an environment, as some predators are dependent on their sensory abilities, thus decrease the predator efficiency on lower trophic levels (Lunt and Smee 2015).

Despite a limited number of studies on how meroplankton are spatially distributed according to a fjordic salinity gradient, they are often found closer to shore together with small copepods, rather than in open water (Hop et al. 2019). Studies from the Kara Sea in the Russian Arctic also suggest that the input of nutrients through rivers may enhance the survival of benthic larvae and extend their feeding period (Fetzer and Arntz 2008). An estuarine turbidity maximum is created due to riverine circulation, causing smaller zooplankton to be trapped close to the rivers (Kulikova, Solokhina, and Samatov 2000). Meroplankton may be particularly sensitive to these entrapment zones and less by advection of water masses due to their often short occurrence in the pelagic (Mileikovsky 1968).

Together with the size and species distribution, zooplankton biomass and diversity are important factors in marine ecosystems (Cauvy-Fraunié and Dangles 2019). Both zooplankton biomass and diversity are documented to be lower in less saline and more stratified water in comparison with more saline and well-mixed water. Thus zooplankton biomass normally increases along a gradient from freshwater influenced to pure marine (Harvey 2001; Estrada et al. 2012). Environmental disturbance, e.g. stress, is known to lower species richness and diversity, and freshwater input and strong salinity gradients are factors controlling these parameters (Witman et al. 2008; Estrada et al. 2012). Additionally, species diversity may increase with increasing depth in the Arctic Ocean (Kosobokova, Hopcroft, and Hirche 2011).

Along with an expected increase in terrestrial and freshwater input due to increasing temperatures, these impacts identify a need for more knowledge on how the Arctic zooplankton community changes.

1.3 Aims and objectives

This thesis aimed to investigate the influence of terrestrial input on the zooplankton community in Isfjorden, Svalbard, along a gradient from the river mouth and glacier plumes to open ocean on three occasions during the 2018 melt season (May, June, August).

Along a gradient from inner sites close to river estuaries and glacier plumes, to outer sites in open water I hypothesize following changes in the zooplankton community:

1. A change in species composition from primarily smaller species (e.g. *Oithona* spp., and *Pseudocalanus* spp.) to larger, more oceanic species, such as *Calanus* spp. Furthermore, along the same gradient, I expect a higher proportion of meroplankton in the innermost parts of the fjord, and the other way around for holoplankton.

2. A change from smaller, more omnivorous copepods in the innermost sites, to larger. more herbivorous zooplankton, mainly grazers and filter feeders, further out in the fjord, peaking at the marine endpoints.

3. An increase in both biomass and diversity from the inner to the outer sites, as a consequence of increased environmental stress in the innermost part of the fjord, due to e.g. freshwater input and high turbidity. In addition, I expect increased biomass as a result of a shift from smaller sized to larger sized zooplankton species.

2. Materials and methods

Sampling was conducted in May, June, and August 2018 in Isfjorden, Svalbard (for further details, see Table 1). Sampling campaigns were organized through the TerrACE project and included several other objectives in addition to those presented in this thesis.

2.1 Sampling area

2.1.1 Svalbard area

Svalbard is an Arctic Archipelago situated between 74° and 81°N, and 10° and 35°E in the Norwegian Arctic (Figure 1). Svalbard is located between the Arctic Ocean in the north, the Norwegian Sea in the south, the Barents Sea in the east, and the West Spitsbergen Shelf in the west, and consists of several islands, where Spitsbergen is the largest (Figure 1). Along the western coast of Spitsbergen warm, and more saline Atlantic water (AW) is transported by the West Spitsbergen Current (WSC) northwards. Colder, less saline Arctic water is transported from the east along the Sørkapp Current, creating a frontal area between the two types of currents. An extensive part of Svalbard's land area is covered by glaciers (approximately 60%) (Hagen et al. 2003) (Appendix II), in addition to a number of rivers leading out to the fjords. Svalbard also has permafrost, being the largest permafrost area in Europe outside Russia (Humlum, Instanes, and Sollid 2003).

2.1.2 Site classification – Habitat categories

To avoid influence of very local conditions and get a more qualified picture on the persistent gradients independent of fjord, the sites were divided into four groups: River estuaries ("River estuary (RE)"), inner ("Inner"), outer ("Outer") and marine endpoints ("Marine"). These habitat categories were selected in order to represent four different habitats that I anticipated would have a different degree of terrestrial influence and have been used throughout the study. "River estuary" habitats were close to rivers, "Inner" habitats were situated in the innermost parts of the fjords, either close to glaciers or close to the shore. "Outer" habitats were mainly in the fjord mouth, further from the shore than the inner stations, while the "Marine" habitats were the sites used as marine endpoints, moreover the least terrestrial influenced sites. Due to the ice cover in May, the two sites B_Ice and T_Ice were used as replacements, both classified as "Inner" habitats. See Appendix (III) for further details on the placements of B_Ice and T_Ice.

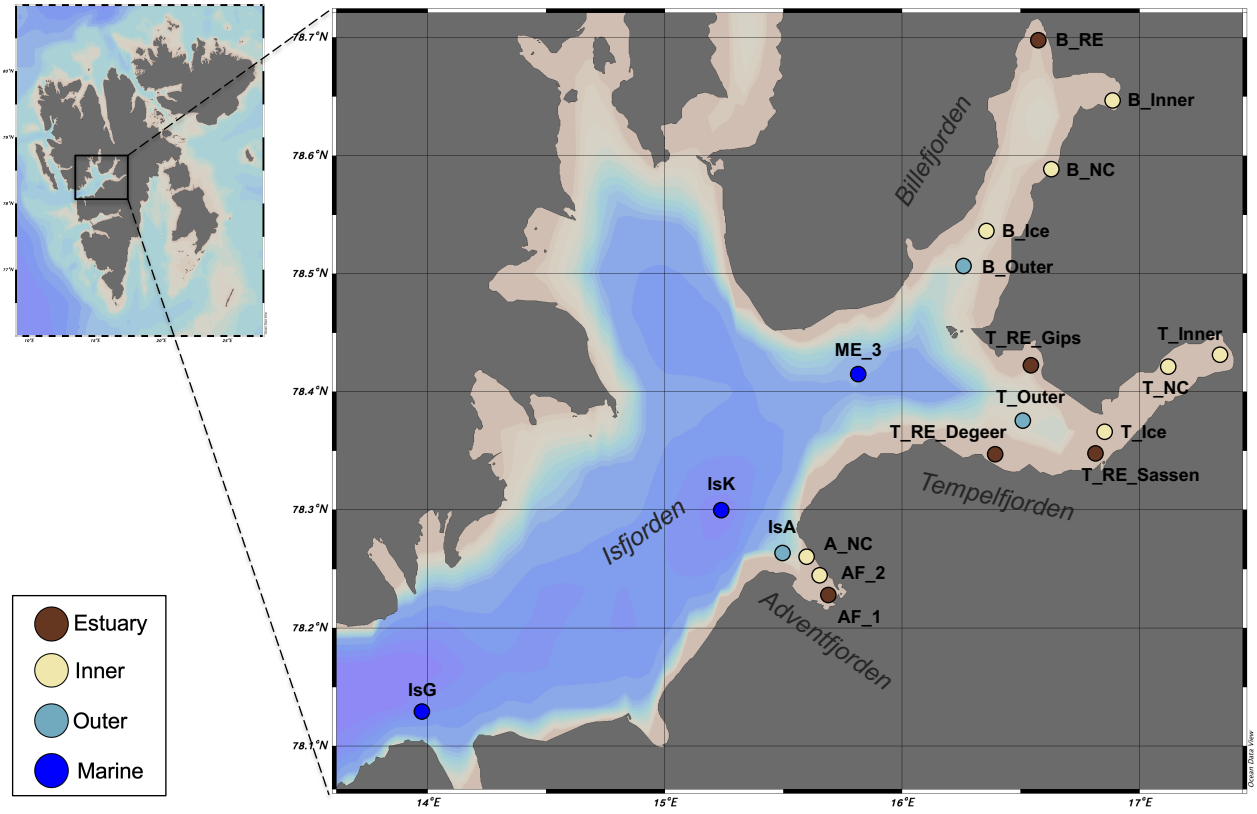

Figure 1: Station map. Svalbard and Spitsbergen in the left panel, Isfjorden, including the inner fjord branches (Adventfjorden, Tempelfjorden, Billefjorden) with stations in the right panel. The brown dots represent the river estuary sites (Estuary), the white dots represent the inner sites (Inner), the turquoise dots represent the outer sites (Outer), and the dark blue dots represent the marine endpoint sites (Marine). Map derived from Ocean Data View.

2.1.3 Site descriptions

The sampling campaigns were carried out in the Isfjorden system, visiting a number of stations along gradients from river estuaries and glaciers to more open water stations in different side-arms of the main fjord. In addition, three marine endpoint stations were sampled in Isfjorden.

Isfjorden

Isfjorden consists of a number of inner fjord arms and bays that differ in the degree of influence from rivers and marine-terminating glaciers (Figure 1). Isfjorden has no distinct sill at its mouth and can, therefore, be directly influenced by the Atlantic water transported by the WSC. The fjord is very wide (approximately 24 and 70 km), and the depth in the fjord system ranges from 55% of the area < 100 m depth, and 25% > 200 meters (Nilsen et al. 2008). Except for the very inner parts, Isfjorden has not been ice-covered since 2005 (Cottier et al. 2007; Muckenhuber et al. 2016). However, some parts of the fjord system, e.g. Tempelfjorden and Billefjorden, are

seasonally ice-covered. Isfjorden is also surrounded by glaciers and rivers that feed the fjords (Appendix II), and especially in the northern parts of the fjord system, numerous glaciers drain to the fjord (Nilsen et al. 2008).

Adventfjorden

Adventfjorden is a side-arm located in the southern part of Isfjorden (Figure 1), with no distinct sill to Isfjorden (Forwick, Baeten, and Vorren 2009). The fjord has no directly glacial contact, but the two rivers entering the fjord, Adventelva and Longyearelva, are glacially fed and transport high concentrations of inorganic particles (Zajaczkowski and Włodarska-Kowalczuk 2007). Adventelva is fed by glacial meltwater from glaciers that have retreated several kilometers from the shoreline (Svendsen et al. 2002). Adventfjorden has not been fully ice-covered since 2007 (Wiedmann et al. 2016), but the river delta freezes in the winter. The fjord and river delta were ice-free when sampling occurred.

Tempelfjorden

Tempelfjorden is a 14 km long fjord arm located at the innermost part of Isfjorden (Figure 1). Similar to Adventfjorden, Tempelfjorden has some topographic barriers, but not a pronounced sill. The glacier Tunabreen discharges directly out in the innermost part of Tempelfjorden (Flink et al. 2015). Additionally, several rivers discharge into Tempelfjorden, leading to a substantial inflow of freshwater, especially during summer. Tempelfjorden is seasonally ice-covered, freezing rather early due to the substantial freshwater input. The rivers are frozen during the winter but open up in the spring, sometimes during May and June.

Billefjorden

Billefjorden is a 30-km long branch of Isfjorden, located in the north-western part (Figure 1). Billefjorden differs from Adventfjorden and Tempelfjorden, by being partially separated from the remaining system through an outer sill (80 m) in the fjord mouth. The sill is followed by a flat central part and another shallower sill (40 m) for so a deeper sill (190 m) in the inner part of the fjord (Forwick, Baeten, and Vorren 2009). Due to the sill, there is less exchange of warm water from Isfjorden; thus, Billefjorden is characterized by more cold, locally formed Arctic water. Billefjorden has two smaller branches in the inner part. In the southernmost, part the glacier Nordenskiöldbreen discharges large amounts of freshwater. The river is frozen in the winter season but opens up in the spring. Billefjorden was seasonally ice-covered, and for that reason, the May campaign was influenced accordingly (2.1.4 Ice conditions).

2.1.4 Ice conditions

The Arctic has a maximum sea ice extent typically in March and April, and a minimum in September (Adakudlu et al. 2019). In addition, local fast ice forms during winter in some fjords, and opens up during the spring. The May sampling campaign was influenced by ice cover in Billefjorden and Tempelfjorden (Appendix III). Thus the innermost stations B_RE, B_Inner, B_NC in Billefjorden, and T_Inner in Tempelfjorden, was replaced by B_Ice and T_Ice, respectively. The ice stations were located as close to the ice edge as possible in both fjords. In June and August, there was no sea ice in the sampling area, and all the planned sampling sites were accessible.

Table 1: Site details. Site name, fjord (AF=Adventfjorden, BF=Billefjorden, TF=Tempelfjorden, IF=Isfjorden), habitat category (River Estuary (RE), Inner, Outer, Marine), date, and which procedure implemented on the specific site (Phys= Physical, environmental measurements, Zoo= Zooplankton sampling).

Site	Fjord	Habitat category	Date	Procedure
AF_1	AF	RE	14.05.18	Phys+zoo
AF_2	AF	Inner	14.05.18	Phys+zoo
A_NC	AF	Inner	14.05.18	Phys+zoo
IsA	AF	Outer	11.05.18	Zoo
IsA	AF	Outer	16.05.18	Phys
B_Ice	BF	Inner	16.05.18	Phys+zoo
B_Outer	BF	Outer	10.05.18	Zoo
B_Outer	BF	Outer	16.05.18	Phys
T_Ice	TF	Inner	15.05.18	Phys+zoo
T_RE_Degeer	TF	RE	15.05.18	Phys+zoo
T_RE_Gips	TF	RE	15.05.18	Phys+zoo
T_RE_Sassen	TF	RE	15.05.18	Phys+zoo
T_Outer	TF	Outer	11.05.18	Zoo
T_Outer	TF	Outer	15.05.18	Phys
ME_3	IF	Marine	11.05.18	Phys+zoo
IsK	IF	Marine	10.05.18	Zoo
IsK	IF	Marine	16.05.18	Phys
IsG	IF	Marine	10.05.18	Zoo
A_F1	AF	RE	18.06.18	Phys+zoo
A_F2	AF	Inner	18.06.18	Phys+zoo
A_NC	AF	Inner	18.06.18	Phys+zoo
IsA	AF	Outer	18.06.18	Phys+zoo
B_RE	BF	RE	20.06.18	Phys+zoo

Table 1. Site details (continued).

Site	Fjord	Habitat category	Date	Procedure
B_Inner	BF	Inner	20.06.18	Phys+zoo
B_NC	BF	Inner	20.06.18	Phys+zoo
B_Outer	BF	Outer	20.06.18	Phys+zoo
T_Inner	TF	Inner	22.06.18	Phys+zoo
T_NC	TF	Inner	22.06.18	Phys+zoo
T_RE_Degeer	TF	RE	22.06.18	Phys+zoo
T_RE_Gips	TF	RE	22.06.18	Phys+zoo
T_RE_Sassen	TF	RE	22.06.18	Phys+zoo
T_Outer	TF	Outer	24.06.18	Phys+zoo
ME_3	IF	Marine	24.06.18	Phys+zoo
IsK	IF	Marine	24.06.18	Phys+zoo
IsG	IF	Marine	23.06.18	Phys+zoo
A_F1	AF	RE	17.08.18	Phys+zoo
A_F2	AF	Inner	17.08.18	Phys+zoo
A_NC	AF	Inner	17.08.18	Phys+zoo
IsA	AF	Outer	18.08.18	Phys+zoo
B_RE	BF	RE	24.08.18	Phys+zoo
B_Inner	BF	Inner	24.08.18	Phys+zoo
B_NC	BF	Inner	24.08.18	Phys+zoo
B_Outer	BF	Outer	08.08.18	Phys+zoo
T_Inner	TF	Inner	20.08.18	Phys+zoo
T_NC	TF	Inner	22.08.18	Phys+zoo
T_RE_Degeer	TF	RE	22.08.18	Phys+zoo
T_RE_Gips	TF	RE	22.08.18	Phys+zoo
T_RE_Sassen	TF	RE	20.08.18	Phys+zoo
T_Outer	TF	Outer	22.08.18	Phys+zoo
ME_3	IF	Marine	24.08.08	Phys+zoo
IsK	IF	Marine	18.08.08	Phys+zoo
IsG	IF	Marine	17.08.18	Phys+zoo

2.2 Physical and biological environmental parameters

2.2.1 Physical environmental parameters - Sampling in the field

The field campaigns were conducted by sampling a total of 18 stations in May, June, and August 2018 in Isfjorden, Svalbard (Table 1). Samples were collected from small boats, the research vessels R/V Clione, and R/V Helmer Hanssen (Appendix I).

Salinity and temperature measurements were obtained with a conductivity, temperature, and depth (~pressure) profiler, CTD (model SAIV 204 or 208), at all stations (Table 1). A Seabird 911CTD plus was used onboard R/V Helmer Hanssen in May (Appendix I).

Light measurements and turbidity (water transparency) were conducted using a Secchi disk (30 cm in diameter). The disk was lowered down to the depth where it could no longer be detected, and the depth was read off to 10 cm accuracy. The disk was lowered down at the side of the boat, not being in the shadow of the sun.

2.2.2 Water samples – Sampling in the field

Water samples were taken at each station at 15 m depth and just under the surface (~ 0 m) with a 10L Niskin water sampler bottle (KC Denmark, Silkeborg). At stations shallower than 15 m, the second sample was taken 2 m above bottom instead of 15 m (Table 2). For each depth, following parameters were measured:

Salinity, temperature, and pH were measured with a portable multiparameter sensor (Hanna Instruments HI98195) from a clean steel bucket filled with water taken directly from the Niskin bottle.

Turbidity was measured in triplicates with a handheld turbidity meter (Thermo Scientific Eutech TN-100).

In addition to the parameters measured out in the field, approximately 15 liters of water from both depths were transported back to the laboratory for further filtration. Samples were stored cold and dark prior to processing at the University Centre on Svalbard (UNIS) laboratory.

2.2.3 Filtration

Water at a given volume (300ml) was filtered for analysis of chlorophyll *a* on 25mm glass fiber (Whatman GF/F, 0.7μm) filters and 5μm nucleopore filters (Nucleopore from Whatman). The water was kept as dark as possible until filtration by turning off the light during filtration. The filters were packed in aluminum foil directly after filtration. The chlorophyll *a* filters were stored at -80 °C until further analysis.

2.2.4 Analyses

Concentrations of chlorophyll *a* were calculated for both size fractions from each depth. Filters were stored at -80°C for so to be extracted in methanol and analyzed on a Turner 10-AU

fluorometer (Turner designs Synnyvale, California). Samples were vortexed and measured on the fluorometer for their total pigment content. To distinguish between intact (chlorophyll *a*) and degraded chlorophyll *a* (phaeophytin), two droplets of 5 % HCl were added to the sample (to convert chlorophyll *a* to pheaophytin), vortexed and measured again. The corrected chlorophyll *a* concentration was calculated by the following formula described by Parsons *et al*. (1984) (Parsons, Maita and Lalli, 1984):

(1) $[\mathbf{Chl-a}] = (\mathrm{Fd} * \tau * (\mathrm{Rb} - \mathrm{Ra})) * (\mathrm{vol.\,methanol}/\,\mathrm{vol.\,filtrated})$

Where *[Chl - a]* is in mg m-3, *Fd* is the calibration factor, τ is the mean acid ratio of pure Chl-*a*, *Rb* is the fluorometer reading before HCl addition, and *Ra* is the fluorometer reading after 5 % HCl addition.

2.3 Zooplankton

2.3.1 Zooplankton – Sampling in the field

Zooplankton were sampled by a vertical haul with a WP2 net (net opening 0.250 m^2, mesh size 60 μm or 200 μm, see Table 2 for detailed information regarding mesh size) from approximately two meters above bottom depth to the surface (see Table 2 for haul depth). At certain stations in May, the mesh size of the net was adjusted from 60 μm to 200 μm, due to problems with clogging of the net by phytoplankton (*Phaeocystis* spp. bloom) (pers. obs.) (Table 2). The entire net was rinsed with seawater and emptied in a bucket with unfiltered seawater. The sample was stored in either air temperature (similar to sea temperature) or a cooler and brought back to the laboratory for further processing

2.3.2 Zooplankton – Laboratory work

Sorting of zooplankton

After the zooplankton samples were brought back to the laboratory, the samples were split into four fractions (see Table 2 for size fractioning) using a Motodo plankton splitter.

Fraction number 1 was fixed in formaldehyde (4%) and stored for identification in plastic bottles. Before fixation, cnidarians and comb jellies were picked out, identified, and counted.

The bottles were then stored in a 4% sea water-formaldehyde solution buffered with hexamine until identification.

Fraction number 2 was used for biomass. The fraction was filtered through a sieve with 60 μm mesh size, put on a plastic bottle, and then filtered directly after on a pre-weighed 47 mm GF/F filter. The filters were after that stored in an enclosed petri dish and frozen at -20 °C. The biomass filters were later dried at 50 ℃ for at least 24 hours and weighed with Mettler Toledo AG204 DeltaRange (precision +/-0.2 mg). The dry weight (DW) was then recalculated from the fraction of the zooplankton sample and the size of the WP2 net, with the following formulas.

(2) Biomass (DW) m^{-2}= DW on filter/diameter of net
(3) Biomass (DW) m^{-3}=(biomass (DW) m^{-2})/haul depth

The DW m^{-2} was calculated by dividing the biomass by the diameter of the net, and the DW m^{-3} was calculated by dividing DW m^{-2} by the haul sample depth.

Fraction number 3 was filtered through a sieve with 60 μm mesh size, put in plastic vials, and stored at -20 °C as an archive sample. These samples were meant as back-up samples and are stored at UiO, Oslo.

Table 2: Overview of the zooplankton samples taken at each site from May to August 2018. Site, date, mesh size of the WP2 net used for the specific sample, haul depth (m), the fraction of the entire sample used for identification and biomass, and additional comments.

Site	Date	Mesh size WP2 net (μm)	Haul depth (m)	Fraction identification	Fraction biomass	Additional comments
AF_1	14.05.18	WP2 (200)	20	$1/8$	$1/8$	
AF_2	14.05.18	WP2 (200)	40	$1/4$	$1/4$	
A_NC	14.05.18	WP2 (200)	40	$1/8$	$1/8$	
IsA	11.05.18	WP2 (200)	95	$1/16$	$1/16$	
B_Ice	16.05.18	WP2 (200)	70	$1/8$	$1/8$	
B_Outer	10.05.18	WP2 (200)	70	$1/16$	$1/16$	
T_Ice	15.05.18	WP2 (200)	100	$1/8$	$1/8$	
T_RE_Degeer	15.05.18	WP2 (200)	40	$1/8$	$1/8$	
T_RE_Gips	15.05.18	WP2 (200)	30	$1/8$	$1/8$	
T_RE_Sassen	15.05.18	WP2 (200)	20	$1/8$	$1/8$	
T_Outer	11.05.18	WP2 (200)	40	$1/16$	$1/16$	
ME_3	11.05.18	WP2 (200)	193	$1/16$	$1/16$	
IsK	10.05.18	WP2 (200)	195	$1/16$	$1/16$	
IsG	10.05.18	WP2 (200)	193	$1/4$	$1/4$	
A_F1	18.06.18	WP2 (60)	18	$1/4$	$1/4$	
A_F2	18.06.18	WP2 (60)	40	$1/4$	$1/4$	
A_NC	18.06.18	WP2 (60)	35	$1/4$	$1/4$	
IsA	18.06.18	WP2 (60)	95	$1/8$	$1/8$	
B_RE	20.06.18	WP2 (60)	10	$1/4$	$1/4$	
B_Inner	20.06.18	WP2 (60)	38	$1/4$	$1/4$	
B_NC	20.06.18	WP2 (60)	13	$1/4$	$1/4$	
B_Outer	20.06.18	WP2 (60)	70	$1/8$	$1/8$	
T_Inner	22.06.18	WP2 (200)	36	$1/8$	$1/8$	
T_NC	22.06.18	WP2 (200)	17	$1/4$	$1/4$	
T_RE_Degeer	22.06.18	WP2 (60)	10	$1/4$	$1/4$	Net broken - sample not complete
T_RE_Gips	22.06.18	WP2 (200)	8	$1/4$	$1/4$	
T_RE_Sassen	22.06.18	WP2 (200)	5	$1/4$	$1/4$	
T_Outer	24.06.18	WP2 (60)	50	$1/8$	$1/8$	
ME_3	24.06.18	WP2 (60)	130	$1/8$	$1/8$	
IsK	24.06.18	WP2 (60)	250	$1/8$	$1/8$	
IsG	23.06.18	WP2 (60)	260	$1/8$	$1/8$	

Table 2. Overview of the zooplankton samples taken at each site from May to August 2018 (continued).

Site	Date	Mesh size WP2 net (μm)	Haul depth (m)	Fraction identification	Fraction biomass	Additional comments
A_F1	17.08.18	WP2 (60)	11	$^1/_8$	$^1/_8$	Detritus
A_F2	17.08.18	WP2 (60)	30	$^1/_8$	$^1/_8$	Detritus
A_NC	17.08.18	WP2 (60)	17	$^1/_8$	$^1/_8$	
IsA	18.08.18	WP2 (60)	80	$^1/_8$	$^1/_8$	
B_RE	24.08.18	WP2 (60)	5	$^1/_{10}$	$^9/_{10}$	
B_Inner	24.08.18	WP2 (60)	50	$^1/_4$	$^1/_4$	
B_NC	24.08.18	WP2 (60)	8	-	1	
B_Outer	08.08.18	WP2 (60)	55	$^1/_4$	$^1/_4$	
T_Inner	20.08.18	WP2 (60)	40	$^1/_4$	$^1/_4$	Mud
T_NC	22.08.18	WP2 (60)	14	$^1/_4$	$^1/_4$	Sediment
T_RE_Degeer	22.08.18	WP2 (60)	10	$^1/_4$	$^1/_4$	Mud
T_RE_Gips	22.08.18	WP2 (60)	5	$^1/_4$	$^1/_4$	
T_RE_Sassen	20.08.18	WP2 (60)	15	$^1/_4$	$^1/_4$	Mud
T_Outer	22.08.18	WP2 (60)	40	$^1/_4$	$^1/_4$	
ME_3	24.08.08	WP2 (60)	200	$^1/_4$	$^1/_4$	
IsK	18.08.08	WP2 (60)	269	$^1/_8$	$^1/_8$	
IsG	17.08.18	WP2 (60)	262	$^1/_8$	$^1/_8$	

Identification of zooplankton

Prior to identification, samples were rinsed out of the plastic bottle using filtered seawater, both bottle and lid were well washed. The sample was then filtered through a sieve with 60μm mesh size and was thereafter left in filtered seawater for 30 minutes to wash out the formaldehyde. After washing, the sample was put in a plastic container of known volume, and filtered seawater added (volume depended on the zooplankton density in the sample). From the plastic container, a pipette (1000-5000 μl) was used to sub-sample a known volume of the total volume, and the sub-sample was placed in a plastic petri dish with a grid. The subsample was after that identified using a light microscope (Leica MZ16 Stereo Microscope - Leica Microsystems (UNIS); Nikon SMZ – 10A Stereo Microscope (UiO)). All individuals in the subsample were identified to the lowest taxa possible and counted. For each sample, at least 300 individuals were counted, hence if the number of individuals in one subsample did not reach 300, several subsamples were identified and counted. In certain samples, one specific taxon was dominating in a high degree (e.g., cirriped nauplii, personal observation); these taxa were then excluded from the number of

300 individuals. When identifying, following literature was used: "Coastal phytoplankton: Photoguide for Northern European Seas" (Kraberg, Baumann, and Dürselen 2010), "Literature compiled by Malin Daase with corrections and contributions from Slawek Kwasniewski" (compendium hand-out, 2016 edition), "World Register of Marine Species (WoRMS)" (Horton et al. 2019). As some species were not possible to determine on morphology alone and genetic analysis was not a part of this study, the level of detailed identification varied from each class. See Table 3 for the final list of taxa. From the subsample, the total number of individuals in the sample was calculated using the fraction of the subsample. Thereafter the number of individuals in the sample was multiplied by the fraction of the net opening to one square meter, assuming 100% efficiency.

(4) Zooplankton abundance (ind. m^{-2}) = Ind./subsample*fraction $_{subsample}$*fraction $_{sample}$*4
(5) Zooplankton abundance (ind. m^{-3}) =(ind. m^{-2})/haul depth

Species richness and diversity

Species richness for each site was calculated as the number of taxa per site, while the species diversity was calculated using the Shannon-Wiener Diversity Index. Shannon-Wiener Diversity Index is an index used for comparing diversity between different habitats (Clarke and Warwick 2001). The index assumes a random selection of individuals from an independent population (Shannon 1948). The index is calculated by using the following formula:

(6) $\boldsymbol{H' = -\sum p_i \ln p_i}$

Where p_i is the proportion of individuals found in species *i* in the sample, and ln p_i is the natural logarithm of this proportion (Shannon 1948; Spellerberg and Fedor 2003). The values of the index (*H'*) normally lie between 1.5 and 3.5, and rarely more than 4. The index increases as both the richness and evenness increase, which gives an estimation of the biological variability at the specific site (Ortiz-Burgos 2016).

Trophic levels

The trophic levels of zooplankton are a composed issue, e.g., a number of taxa characterize as more than one trophic level, moreover, shift from one life stage to another. Aware of the complexity, the classification is based on previous literature, also dividing Arctic zooplankton

into groups based on feeding position in the food web (Blachowiak-Samolyk et al. 2007; J. T. Turner et al. 2001).

2.4 Data analyses

2.4.1 Physical and biological environmental parameters

The normality of data was tested using the Shapiro-Wilk test (Shapiro and Wilk 1965), and the significance of difference was tested with either a one-way ANOVA (data normally distributed) or a Kruskal-Wallis Test (data not normally distributed). Tests were implemented in R Studio (Version 1.1.423 – © 2009-2018), using included R functions.

The boxplots of the physical environmental parameters (Figures 3, 4) were produced in R Studio. The data were grouped as the habitat categories ("Estuary", "Inner", "Outer", "Marine") using the *dplyr* as a part of *tidyverse* (Wickham 2016). After that, *ggplot2* (Wickham 2016), was used for producing the boxplots. For further details, see Appendix (XI). The biological, environmental parameter chlorophyll *a* (Figure 4) was handled in Microsoft © Excel © (Version 14.7.3), calculated the following way: For each month, the habitat categories were grouped, and the mean for each group was calculated. The bulk chlorophyll *a* of small cells was calculated from the total (GF/F) excluded the large cells (5 µm). From the mean of each group, a regular bar graph of relative abundance was produced (Figure 4).

2.4.2 Environmental – zooplankton gradients

Two different ordination methods were used: Detrended Correspondence Analysis (DCA) (Figure 10) and Canonical Correspondence Analysis (CCA) (Figure 11, Tables 4, 5). For both analyses, the same zooplankton data matrix was used, processed in Microsoft Excel. The zooplankton data matrix included individuals abundance per m^3, thereafter log-transformed (log(x+1)). For both ordination analyses, the juvenile stages of the taxa were grouped as one taxon (e.g., *Calanus* spp. stage I-V was grouped with adult *Calanus* spp., resulting in only "*Calanus* spp."). This was implied to remove the seasonality caused by the seasonal development of one taxon since the scope of this study was to investigate differences in species composition.

Detrended Correspondence Analysis (DCA)

DCA is a multivariate ordination technique that extracts the main patterns of large species-rich datasets along an axis (Hill and Gauch 1980). The DCA was developed to reduce the defects from a CA (Canonical Analysis): The arch effect, and compression of the ends of the gradient. The first defect appears as a consequence of the unimodal species response curve and makes the axis hard to interpret. The second defect may cause the spacing between the samples (or species) along the first axis not to be related to the amount of change and thus can be misinterpreted. To correct for these artifacts, DCA was developed by Hill and Gauch in 1980 (Hill and Gauch 1980). For the improvement of CA, DCA implemented two steps; the first axis is split up in a number of segments, which may be defined, thereafter, rescaling of each segment so that each segment has a mean value of zero along the second axis. These improvements flatten out the arch effect and make a DCA often better suited for ecological data with more than one explanatory variable, rather than a CA (Correa-Metrio et al. 2013). Similar to CA, the first and second axis can be read off individually, where the first axis explains the most variation, followed by the second axis. The DCA diagram (Figure 10) was produced in R Studio, using the packages *vegan* (Oksanen et al. 2019), *ggplot2* (Wickham 2016), and *goeveg* (Goral and Schellenberg 2018).

Canonical Correspondence Analysis (CCA)

CCA is a multivariate constrained ordination technique, parallel to CA, that extracts large gradients from a dataset of several explanatory variables (Braak 1986). CCA measures the strength of the association between two canonical variates, where the variates in the analysis are the sum of the variables. In this matter, the CCA allows one to test each variable (variation partitioning) and determine the variation explained by the specific variable. It is thus possible to exclude individual variables and look at the variation explained by the residuals. In this study, CCA was implemented to test how much variation the different parameters explained. In addition, to highlight the variability explained by the spatial structure and not the parameters directly linked to seasonality. The parameters were tested one by one, and the variation explained can be seen in Table 4. Also, each parameter was tested by excluding “Julian day” and “Month”, and the explained variability visualized in a diagram (Figure 11, Table 5). The zooplankton data were log-transformed, y= log (x+1), and the environmental variables were log-transformed to reduce skewness. The CCA diagram (Figure 11) was conducted in R Studio, where the analyses and diagram were implemented with *vegan* (Oksanen et al. 2012).

2.4.3 Zooplankton

The calculation of the zooplankton data, such as the total number of individuals and biomass per sample, was conducted in Microsoft Excel, and the plots were produced in R Studio. Relative and total abundance of all zooplankton, holo- and meroplankton, and trophic levels (Figures 5, 6, 7), and biomass (Figure 8) were produced using *ggplot2* (Wickham 2016), further details can be seen in Appendix (XI). The calculation of species richness (taxon per site) was conducted in Microsoft Excel, and the species diversity index (Shannon-Wiener) was calculated in R Studio, using *vegan* (Oksanen et al. 2019), function *diversity*.

2.4.4 Maps and pictures

The map (Figure 1) was produced in Ocean Data View (2008 © Reiner Schlitzer), with later alterations in Microsoft © Powerpoint © (Version 14.7.3), which was also used to edit the pictures used.

3. Results

3.1 Physical and biological environmental parameters

In order to describe the overall patterns, average values for each sample habitat category ("Estuary", "Inner", "Outer", "Marine") were calculated across all fjord arms. In the plots, however, different symbols are used to indicate the respective locations.

3.1.1 Temperature and salinity

Surface temperatures (Figure 2A) increased from ~0 to ~7.5°C from May to August in all habitat categories and showed significant differences between the three months (Kruskal-Wallis Test, $p=1.89*10^{-9}$). The variation was greatest at the innermost habitats in August, where the surface temperature ranged from 3.7℃ (BF) to 7.1℃ (AF). There were no significant differences between the habitat categories within each month (One-Way ANOVA, May: p= 0.677, June: p= 0.217, August: p= 0.979). The temperatures at 15m displayed the same patterns, but with slightly lower variation throughout the season (~0 to ~6°C) (Appendix IV). The surface salinity (Figure 2B) showed large variations from May to August, especially in the river estuary and inner habitats, and was significantly different comparing the three months

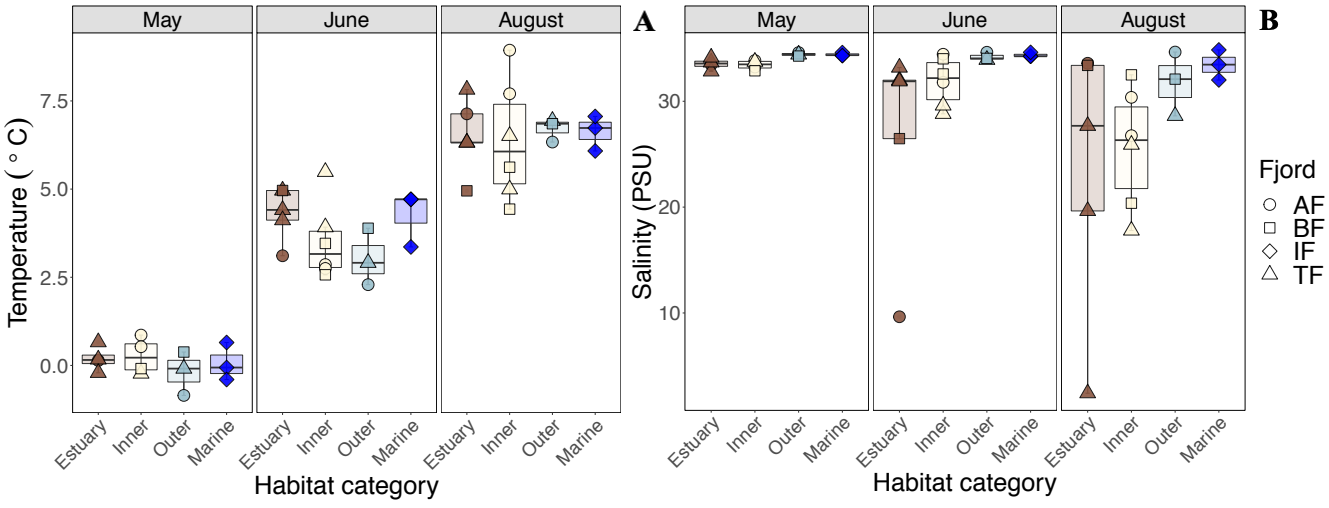

Figure 2: Temperature (A) and salinity (B). Temperature (°C) and salinity (PSU) measured in the surface in May, June, and August. The sites are classified as habitat categories: River estuaries (Estuary, brown), inner (Inner, white), outer (Outer, turquoise) or marine endpoints (Marine, blue), and each fjord is represented as a shape (Adventfjorden (AF)=circle, Billefjorden (BF)=square, Isfjorden (IF)=diamond, Tempelfjorden (TF)= triangle).

(Kruskal-Wallis Test, p=0.0058). The surface salinity in May showed low variability in all habitat categories, moreover, significant differences between the habitats (One-Way ANOVA, p=0.011). However, in June and August, a different pattern was found (Figure 2B). In June, the mean salinity showed a pattern of decrease at the river estuary habitats, and even more profound in August (Figure 2B). At the same time, the variation between the habitats increased (~9 to ~33 PSU in June, ~2 to ~33 PSU in August) (Figure 2B). The same trend from May to August was seen at the inner habitats, with lower salinity in June, followed by even lower in August (~17 PSU in TF). In the outer and marine habitats, the salinity showed little variation from May to June. However, a slightly lower salinity was shown in August. The habitats had different salinity in June (Kruskal-Wallis, p=0.032), but not in August (Kruskal-Wallis, p=0.148) (Figure 2B). The salinity at 15m showed the same patterns, but with much lower variability (~32 to ~36 PSU) (Appendix IV).

3.1.2 Light conditions

The surface turbidity (Figure 3A) showed large variability from May to August and differed significantly between the months (Kruskal-Wallis, p=0.001). However, not between the habitats within the months (One-Way ANOVA, May: p=0.138, June: p=0.398, August: p=0.172). Despite no significant differences, all months showed a slight decrease in turbidity along the gradient from inner to outer habitats (Figure 3A). The variation in August was, moreover, quite immense, as a result of an outlier site in Tempelfjorden, showing the highest turbidity in all sites (~298 NTU). The turbidity at 15m showed a similar pattern to the surface turbidity, but with lower values (~0-40 NTU) (Appendix IV). The Secchi depth (Figure 3B) was significantly different between the three months (Kruskal-Wallis, $p=9.12*10^{-6}$) and decreased from May to June in all habitat categories, from the innermost to the outermost sites. The Secchi depth from August showed a similar trend as the data from June, with a slight increase of the mean value in all habitat categories except for the outermost sites (Figure 3B). The data from June and August showed the same pattern, in addition to significant differences between the habitat categories (June: Kruskal-Wallis, p=0.0212, August: One-Way ANOVA, p=0.002). The Secchi depth was low in river estuaries and inner habitats (~1-4m), whereas it increased slightly in the outer and marine habitats (~3-8m) (Figure 3B). The innermost sites were characterized with considerable variation within all months, especially in May, ranging from ~3 m depth to ~13 m depth (Figure 3B).

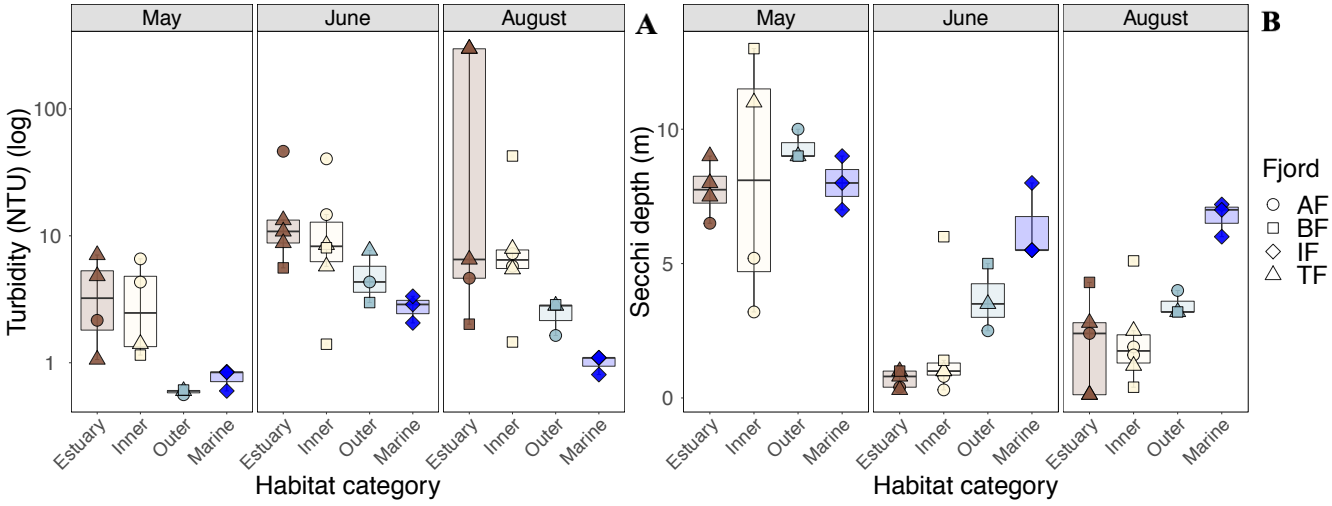

Figure 3: Turbidity (A) and Secchi depth (B). Surface turbidity (NTU) and Secchi depth (m), measured in May, June, and August. The sites are classified as habitat categories: River estuaries (Estuary, brown), inner (Inner, white), outer (Outer, turquoise") or marine endpoints (Marine, blue), and each fjord is represented as a shape (Adventfjorden (AF)=circle, Billefjorden (BF)=square, Isfjorden (IF)= diamond, Tempelfjorden (TF)= triangle).

3.1.3 Food availability: Chlorophyll *a*

Chlorophyll *a* (Figure 4) was measured in the surface and showed variability among habitats, both in terms of total chlorophyll *a* (~0.2-3 µg chl-a L^{-1}), but also with respect to size (smaller or larger than 5 μm). In May, the total chlorophyll *a* concentration was low in the innermost sites (0.27 µg/L) but showed a pattern of increasing concentration along the fjord gradient to the marine endpoints (3.13 µg/L) (Figure 4). In June, both the relative and total chlorophyll *a* concentration was more similar within the habitats, showing a more substantial fraction of small than large cells and total value at approximately 1 µg/L, including a slight increase in the outermost sites (Figure 4). In August, the total concentration showed an increase from the estuaries to the inner habitats, followed by a minor decrease in the outermost sites. Similar, the fraction of large cells increased from river estuaries to inner habitats but decreased to the outermost sites (Figure 4). From the chlorophyll *a* measured at 15 m, the pattern looked somewhat similar, however; with a more distinct pattern of increasing concentrations along a gradient from inner to outer, in addition to some minor differences in the fraction of small and large cells (Appendix V).

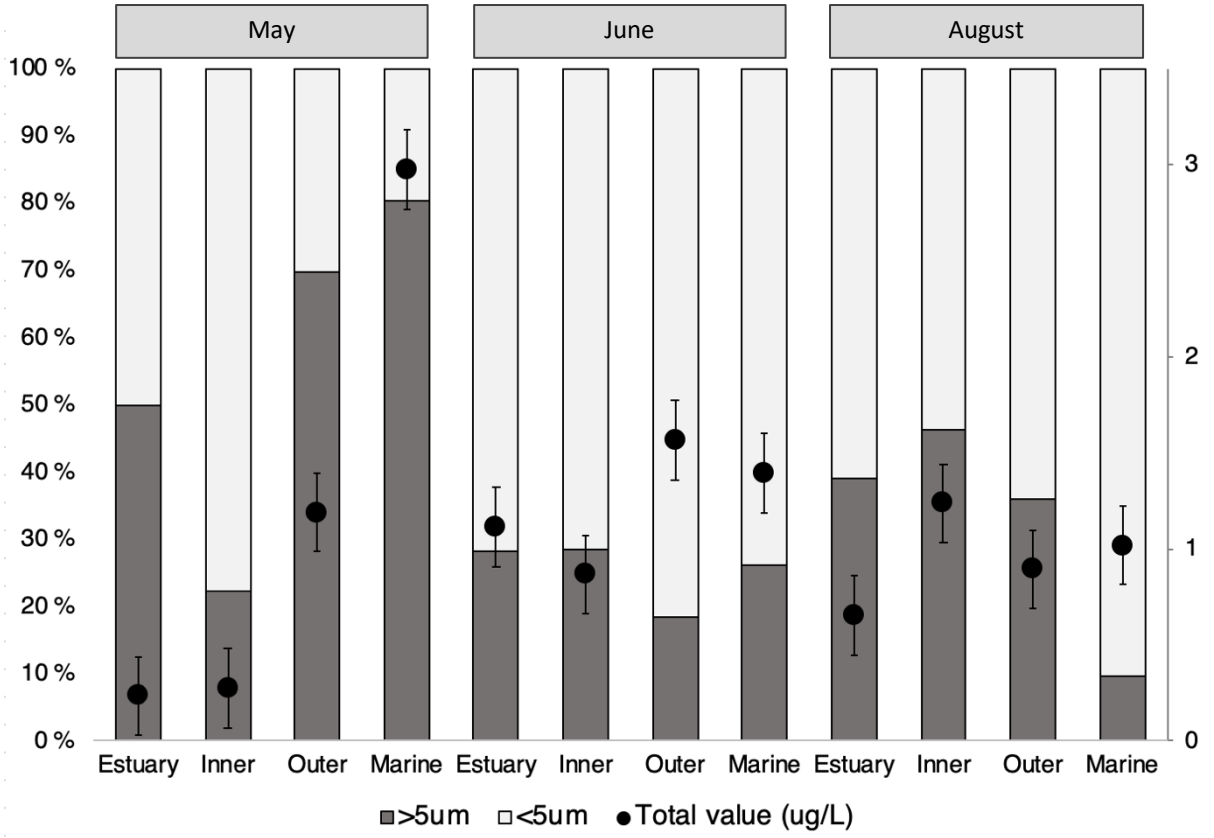

Figure 4: Chlorophyll *a*. The relative and total concentration of chlorophyll *a* (µg/L) measured in the surface in May, June, and August. The first y-axis displays the relative abundance of the two size fractions, cells larger than 5µm (white) and cells smaller than 5µm (grey). The second y-axis displays the total concentration of chlorophyll *a*, measured as µg/L. The sites are classified as habitat categories: River estuaries (Estuary), inner (Inner), outer (Outer), or marine endpoints (Marine).

3.2 Zooplankton communities

3.2.1 Total and relative and abundance

The total number of individuals (Figure 5) was highest in the river estuary (~20.000 ind. m^{-3}) and outer habitats (~12000 ind. m^{-3}), and lowest in the marine endpoints (~700 ind. m^{-3}). Meroplankton (mainly cirriped nauplii) dominated the abundance in all habitats in May, except for the marine sites, which also showed low zooplankton abundance compared to the other habitats (Figure 5). In June, the total abundance was highest in the river estuary habitats (~5000 ind. m^{-3}) and decreased to the inner and outermost sites (~2500 ind. m^{-3}). In general, June had low zooplankton abundances compared to May. Parallel to the total abundance, the abundance of meroplankton (mainly cirriped nauplii) decreased from the river estuaries to the marine endpoints, while the other groups kept rather similar abundances from inner to outer habitats

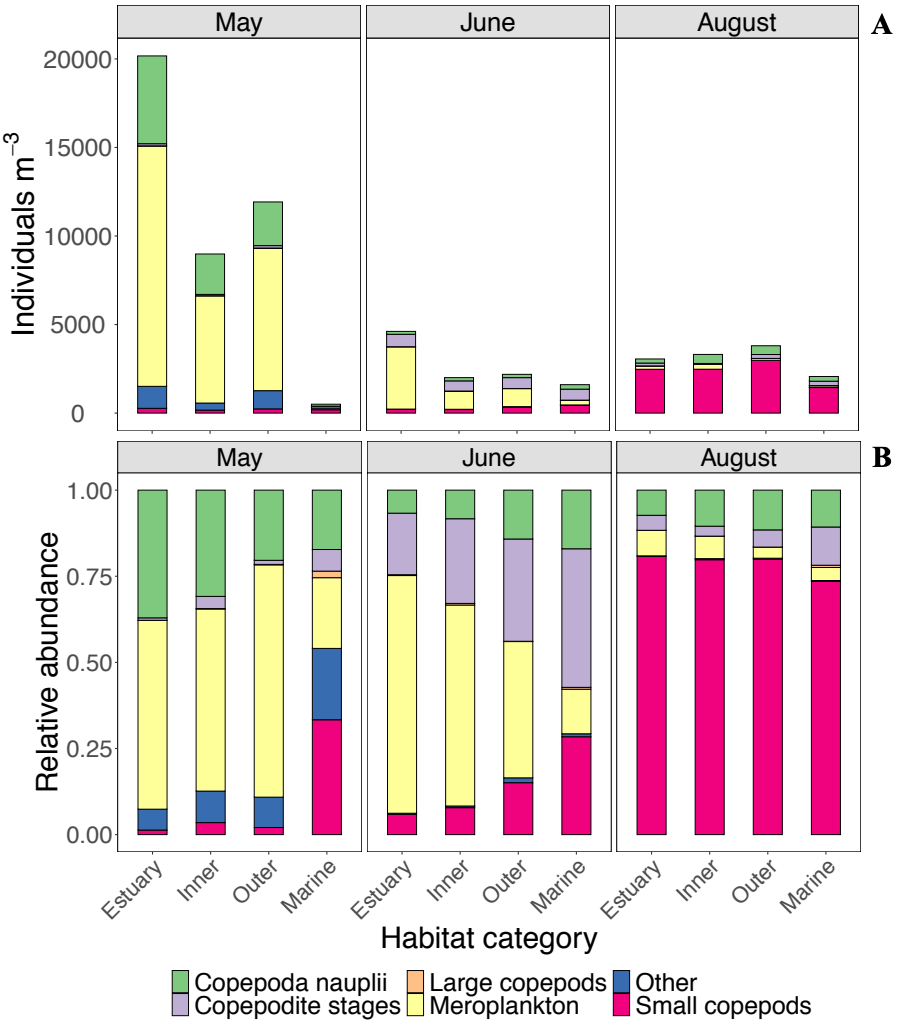

Figure 5: Total (ind. m^{-3}) (A) and relative zooplankton abundance (B). The total and relative abundance of zooplankton shown from May to June, classified as river estuaries (Estuary), inner (Inner), outer (Outer), or marine endpoints (Marine). The different groups of zooplankton are marked as green (copepod nauplii), purple (large copepods, copepodite stages), orange (large copepods), yellow (meroplankton), blue (other) and pink (small copepods). Shown are mean values for all fjords studied.

(Figure 5). In August, the total abundance increased slightly from the river estuary (~3000 ind. m^{-3}) to the outer habitats (~4000 ind. m^{-3}), for so to decrease again in the marine endpoints (Figure 5). Small copepods were dominating in August, mainly *O. similis*, followed by *Pseudocalanus* spp. and *Microcalanus* spp. The relative abundance from May showed a decrease in the fraction of copepod nauplii from the innermost (~35%) to the outermost sites (~18%). In addition, there was a dominance of meroplankton in the estuary, inner and outer habitats (>50% of the total abundance), predominantly cirriped nauplii and a few polychaete larvae (Figure 5). The fraction of meroplankton decreased in the marine sites (~20%). The relative abundance (Figure 5) of small copepods and other zooplankton, mainly euphausiid larvae, were, however, the highest within the marine sites. In June, there was a more evident

trend along the gradient from the estuary to marine habitats, showing an increase in copepod nauplii, large juvenile copepods (mainly *Calanus* spp.), and small copepods (mainly *O. similis* and *Pseudocalanus* spp.) (Figure 5). Similarly, there was a decrease in meroplankton, predominantly cirriped nauplii, and a smaller fraction of bivalve veliger, from the inner (~70%) to outer sites (~12%). In August, the variation from river estuaries to marine habitats was relatively small, and the fraction of small copepods dominated (~70%) all four habitats, mainly *O. similis*, followed by *Pseudocalanus* spp. and *Microcalanus* spp. (Figure 5). There was a minor increase in the abundances of *Calanus* spp. (copepodite stages) from inner to outer habitats. The total abundance (ind. m^{-2}) (Appendix VI) showed the same high numbers in May; however, in June and August the abundance showed an increase along the gradient from river estuary habitats to marine endpoints.

Table 3: Total list of taxa. The total list of taxa throughout May, June, and August for all habitats. The list shows the category of zooplankton group (Figure 5), and the trophic mode; herbivores (H), omnivores (O), or carnivores (C) (Figure 7).

Taxa	Group	Trophic mode	Taxa	Group	Trophic mode
Copepoda nauplii			**Gelatinous taxa**		
Calanoida (nauplii)	Copepoda nauplii	H	*Aglantha digitale*	Other	C
Copepoda (nauplii)	Copepoda nauplii	H	*Beröe cucumis*	Other	C
Small copepods			*Dimophyes arctica*	Other	C
Microcalanus spp.	Small copepods	O	*Mertensia ovum*	Other	C
Microsetella norvegica	Small copepods	O	**Other**		
Oithona atlantica	Small copepods	O	*Alentia gelatinosa*	Other	O
Oithona similis	Small copepods	O	Chaetognatha	Other	C
Oncaea spp. (juvenile)	Small copepods	O	Euphausiidae (larvae)	Other	O
Pseudocalanus spp.	Small copepods	H	*Fritillaria borealis*	Other	H
Triconia borealis	Small copepods	O	Isopoda (larvae)	Other	O
Large copepods			*Limacina helicina* (veliger)	Other	H
Calanus spp.	Large copepods	H	*Oikopleura* spp.	Other	H
Metridia longa	Large copepods	O	*Parasagitta elegans*	Other	C
Meroplankton			*Themisto abyssorum*	Other	C
Bivalvia (veliger)	Meroplankton	O	*Thysanoessa inermis*	Other	O
Cirripedia (nauplii)	Meroplankton	H			
Cirripedia (cypris)	Meroplankton	O			
Echinodermata (larvae)	Meroplankton	O			
Hyas araneus (larvae)	Meroplankton	O			
Polychaeta (larvae)	Meroplankton	O			
Trochophora (larvae)	Meroplankton	O			
Zoea (larvae)	Meroplankton	O			

3.2.2 Holoplankton and meroplankton

The total abundance of holoplankton (Figure 6A) showed the greatest values in the river estuary habitats in May (>6000 ind. m^{-3}), with a dominance of copepod nauplii. This dominance was similar in all the habitats in May except the marine endpoints, showing much lower total abundance (~500 ind. m^{-3}) (Figure 6A). June was characterized by a dominance of *Calanus* spp. followed by nauplii stages, *O. similis,* and *Pseudocalanus* spp. In contrast, August was dominated by *O. similis* in all habitats (Figure 6A). The total abundance of meroplankton

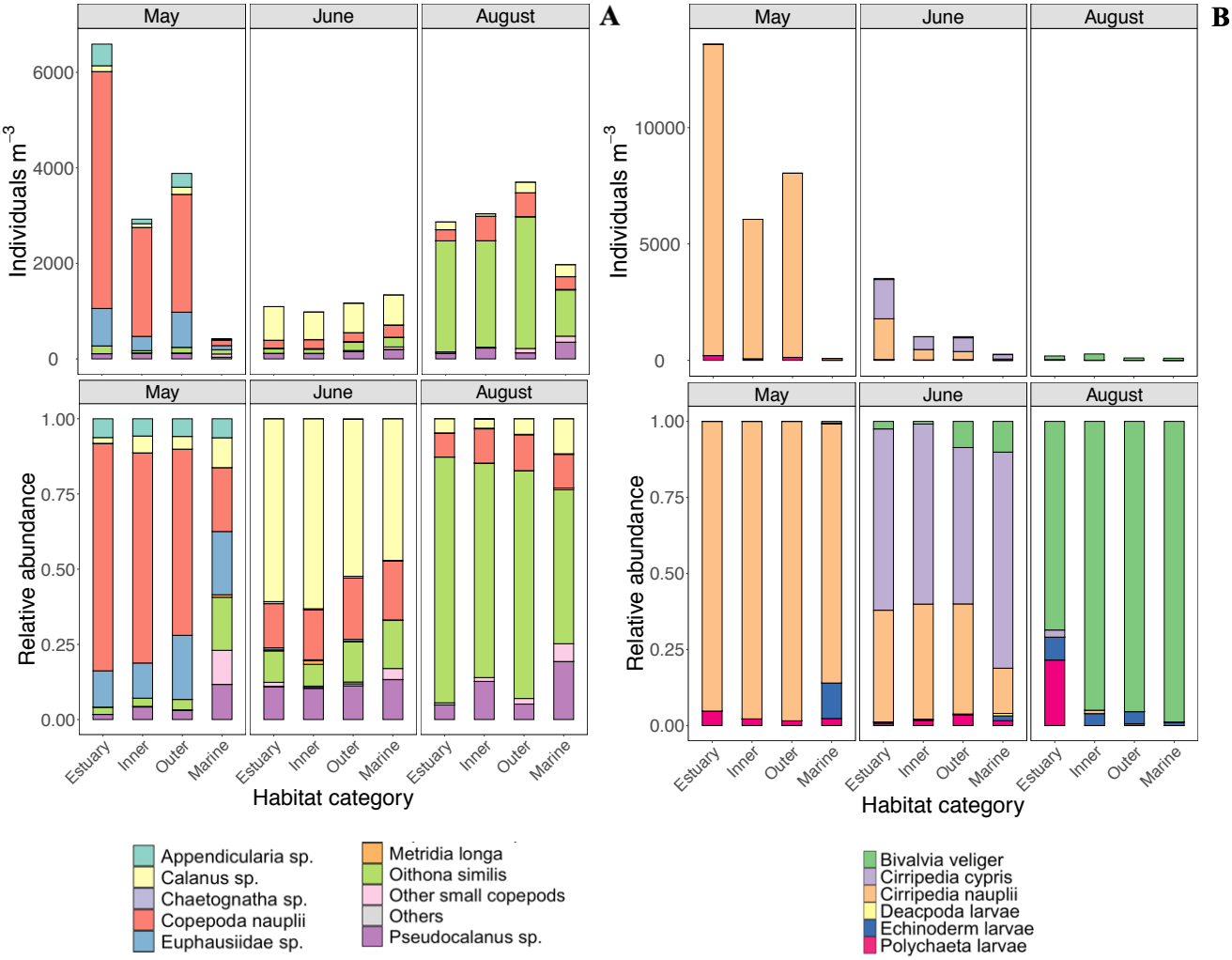

Figure 6: Total (ind. m^{-3}) and relative abundance of holoplankton (A) and meroplankton B). The relative and total abundance of holoplankton and meroplankton are shown from May to June, classified as river estuary (Estuary), inner (Inner), outer (Outer), or marine endpoints (Marine). The different groups of holoplankton are marked as turquoise (Appendicularia spp.), yellow (*Calanus* spp.), purple (Chaetognatha spp.), blue (Euphausiidae spp.), orange (*Metridia longa*), green (*Oithona similis*), pink (other small copepods), grey (others), purple (*Pseudocalanus* spp.). The different groups of meroplankton are marked as green (bivalve veliger), purple (cirriped cypris), orange (cirriped nauplii), yellow (decapoda nauplii), blue (echinoderm larvae) and pink (polychaete larvae). Shown are mean values for all fjords studied.

(Figure 6B) showed higher abundances at the river estuary, inner and outer habitats in May (~6000-14.000 ind. m^{-3}), in comparison with the marine endpoints, but also the other months. A clear dominance of cirriped nauplii characterized May. The total abundances showed a decreasing pattern from May to August, moreover a shift from cirriped nauplii and cypris, to bivalve veliger (Figure 6B).

3.2.3 Trophic level assignments

The relative abundance of herbivores, omnivores, and predators (Figure 7A) showed a dominance of herbivores in May, followed by a shift to omnivores in August. The predator species showed only minor abundances relative to the herbivores and omnivores but can be seen as total abundance in Figure 7B. The predators showed an abundance of mainly *Parasagitta elegans* and *Beröe cucumis* at the river estuary and inner habitats in May, followed by zero individuals in the outermore habitats. In June and August, a dominance of *P. elegans* was detected, in addition to a few arrow worms (Chaetognatha spp.) at the inner and outer habitats in June (Figure 7B).

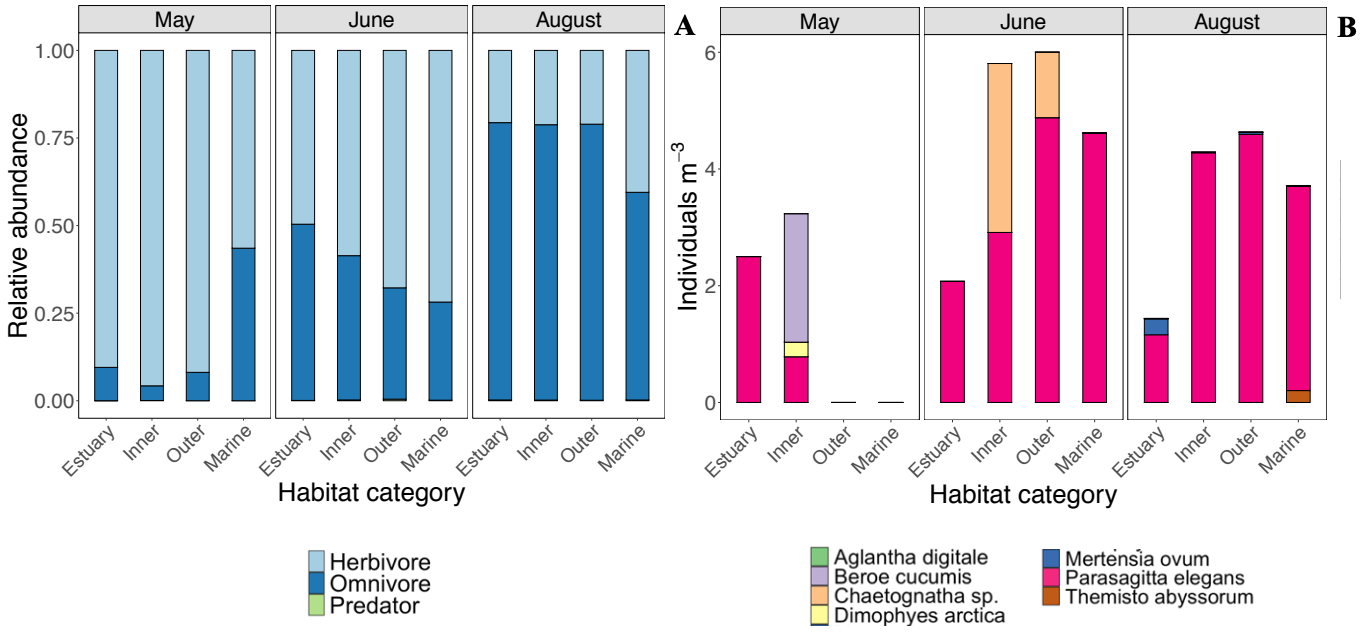

Figure 7: The relative abundances of herbivores, omnivores, and predators (A), and the total abundance of predators (B) (ind. m^{-3}). The relative abundance, classified as herbivores (color) and omnivores (color), and predators, displaying green (*Aglantha digitale*), purple (*Beröe cucumis*), orange (Chaetognatha spp.), yellow (*Dimophyes arctica*), blue (*Mertensia ovum*), pink (*Parasagitta elegans*) and brown (*Themisto abyssorum*). Data shown from May to June, classified as river estuary (Estuary), inner (Inner), outer (Outer), or marine endpoints (Marine). Shown are mean values for all fjords studied.

3.2.4 Zooplankton biomass

The biomass (dry weight, g m^{-3}) of zooplankton (Figure 8) showed no significant differences between the months (Kruskal-Wallis, p=0.107), nor between the habitats in each month (Kruskal-Wallis, May: p=0.058, June: p=0.062, August: p=0.455). In May, the overall biomass was highest at the inner habitats, which also showed the most considerable variation (~0.02-0.55 g). In June, there was a minor trend of increasing biomass from the inner sites to the outermost sites, but again, no significant difference. In contrast to May and June, the biomass from August showed an increase from the innermost sites to the marine, despite of no significance in differentiation (Figure 8).

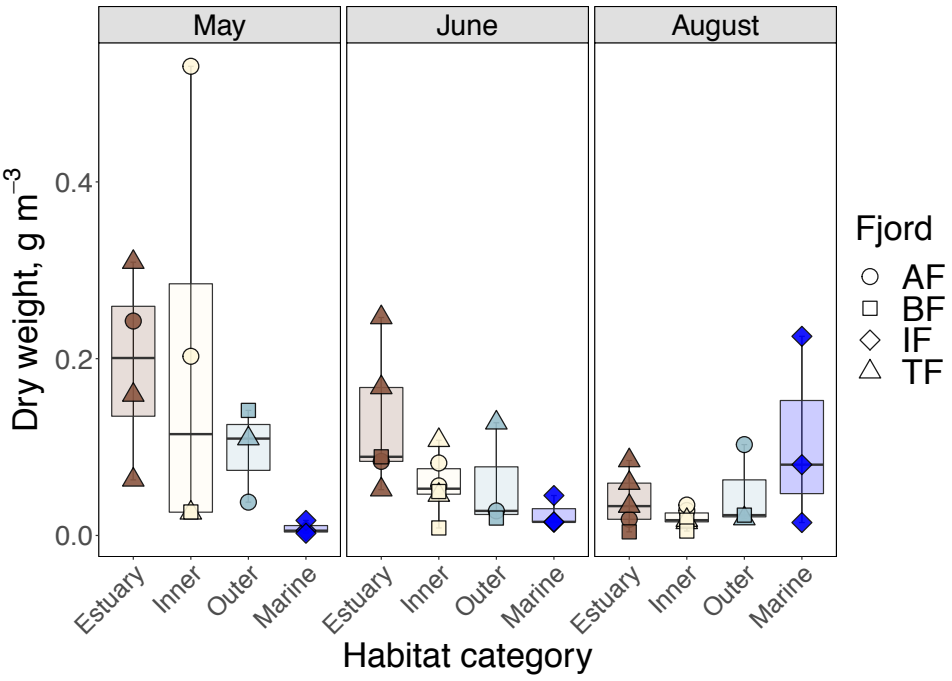

Figure 8: Biomass (dry weight, g m^{-3}). The biomass measured in May, June, and August. The sites are classified as habitat categories: River estuaries (Estuary, brown), inner (Inner, white), outer (Outer, turquoise") or marine endpoints (Marine, blue), and each fjord is represented as a shape (Adventfjorden (AF)=circle, Billefjorden (BF)=square, Isfjorden (IF)= diamond, Tempelfjorden (TF)=triangle).

3.2.5 Species diversity (Shannon Wiener Diversity Index) and richness

Shannon Wiener Diversity Index (Figure 9A) showed no significant difference between the three months (One-Way ANOVA, p=0.43). However, a trend of increasing diversity from river estuaries to the marine habitats was seen, and all three months showed significant differences between the habitats (One-Way ANOVA, May: p=0.002, June: p=0.016, August: p=0.011) (Figure 9A). In the estuary and inner habitats, there was a small decrease in June, followed by

an increase in August. In the outer habitats, there was an increase in June, but with large variations within the class, followed by a decrease in August (Figure 9A). In the marine endpoints there was an overall decrease from May to August, but also here with large variations within the habitats in August. The number of taxa (species richness) (Figure 9B) was similar to the species diversity in comparison of the months (no significant difference between the months, Kruskal-Wallis, p=0.222). However, when comparing the habitats within each month, May and June showed no significant difference (One-Way ANOVA, May: p=0.96, June: p=0.324), whereas, within August, differences were found between habitats (Kruskal-Wallis, p=0.019) (Figure 9B). In addition, the species richness in June showed a decrease from the inner and outer sites to the marine habitats, the opposite from May and August.

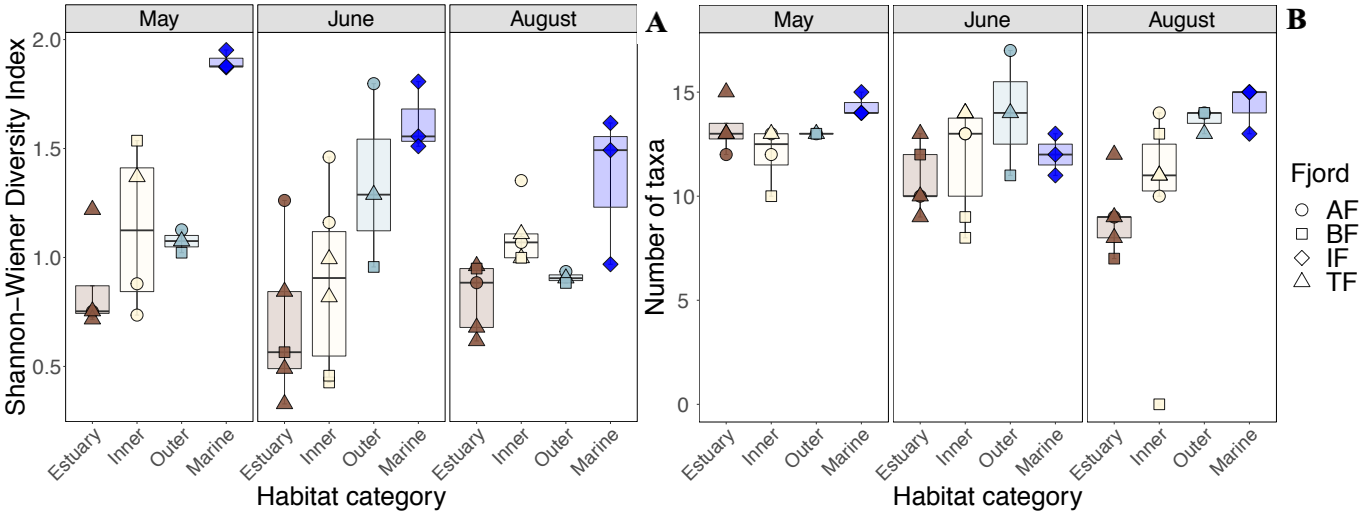

Figure 9: Shannon Wiener Diversity Index (A) and species richness (B). Shannon Wiener Diversity Index and species richness (number of taxa) calculated for May, June, and August. The sites are classified as river estuaries (Estuary, brown), inner (Inner, white), outer (Outer, turquoise) or marine endpoints (Marine, blue), and each fjord is represented as a shape (Adventfjorden (AF)=circle, Billefjorden (BF)=square, Isfjorden (IF)= diamond, Tempelfjorden (TF)= triangle).

3.3 Environmental drivers of zooplankton community structure

As seen in the physical and biological environmental parameters, differences and variation were found both seasonally and spatially. Based on these findings, we investigated if and how the zooplankton community was impacted by the environment.

3.3.1 DCA (individuals m^{-3})

DCA axis 1 explains 31.3% of the total zooplankton variation and is mostly related to the parameters Julian day, surface temperature, and Secchi depth, separating the three months apart (Figure 10). Surface temperature increases along with August, whereas the Secchi depth is positively related to May. The first axis separates the months (May, June, August), whereas the second axis is mostly separating the habitat categories (Estuary, Inner, Outer, Marine) (Figure 10). Also, DCA axis 2 explains less variation (8.9%) and is negatively correlated to chlorophyll a, salinity, and depth (Figure 10). In addition to environmental parameters, depth and Julian day, the most abundant taxa are shown in relation to their distribution, showing a pattern of bivalve veliger and copepod nauplii positively related to August, and cirriped nauplii,

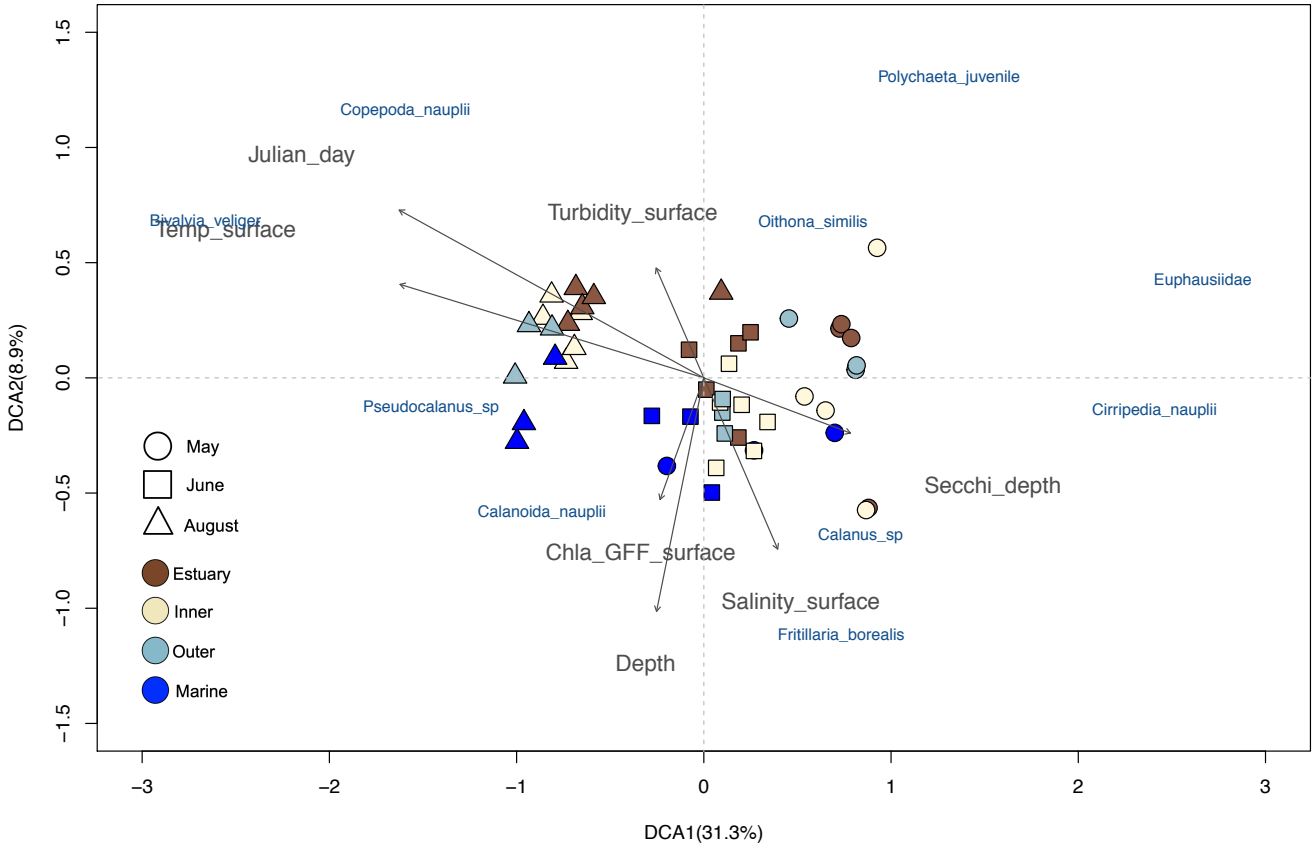

Figure 10: DCA diagram. DCA diagram showing community data (individuals m^{-3}) from May (circles), June (squares), and August (triangles), classified as river estuary (brown), inner (white), outer (turquoise) and marine (blue) habitats. The zooplankton data is log-transformed (log (x+1)), and 30% of the most abundant (numerous) taxa are shown in dark blue (bivalve veliger, Copepoda nauplii, *Pseudocalanus* spp., Calanoida nauplii, *Fritillaria borealis*, *Calanus* spp., *Oithona smilis*, Polychaeta juveniles, cirriped nauplii, euphausiid larvae). Environmental variables, in addition to depth and Julian day, are passively placed on top of the diagram (chlorophyll *a*, depth, Julian day, surface salinity, Secchi depth, surface temperature, and surface turbidity).

Calanus spp. and euphausiid larvae positively correlated with May (Figure 10). Related to the innermost habitats are polychaete larvae and *O. similis*, while Calanoida nauplii and *Fritillaria borealis* are more associated with the marine endpoints.

3.3.2 CCA (individuals m^{-3}): Variation excluding seasonality

The CCA diagram (Figure 11) shows each site categorized as habitats, excluding the variation explained by the parameters mostly related to season (Month, Julian day). Both axes show eminently low eigenvalues, which indicates that seasonality explains the most variation (33%), followed by temperature (22%) (Table 3). CCA axis 1 with an eigenvalue of 8.1% shows a pattern of separation between the marine/outer habitats, and the inner and estuary habitats. It indicates that despite low eigenvalues, there is a spatial pattern independently from the seasonality (Figure 11). The environmental parameters positively correlated with the marine

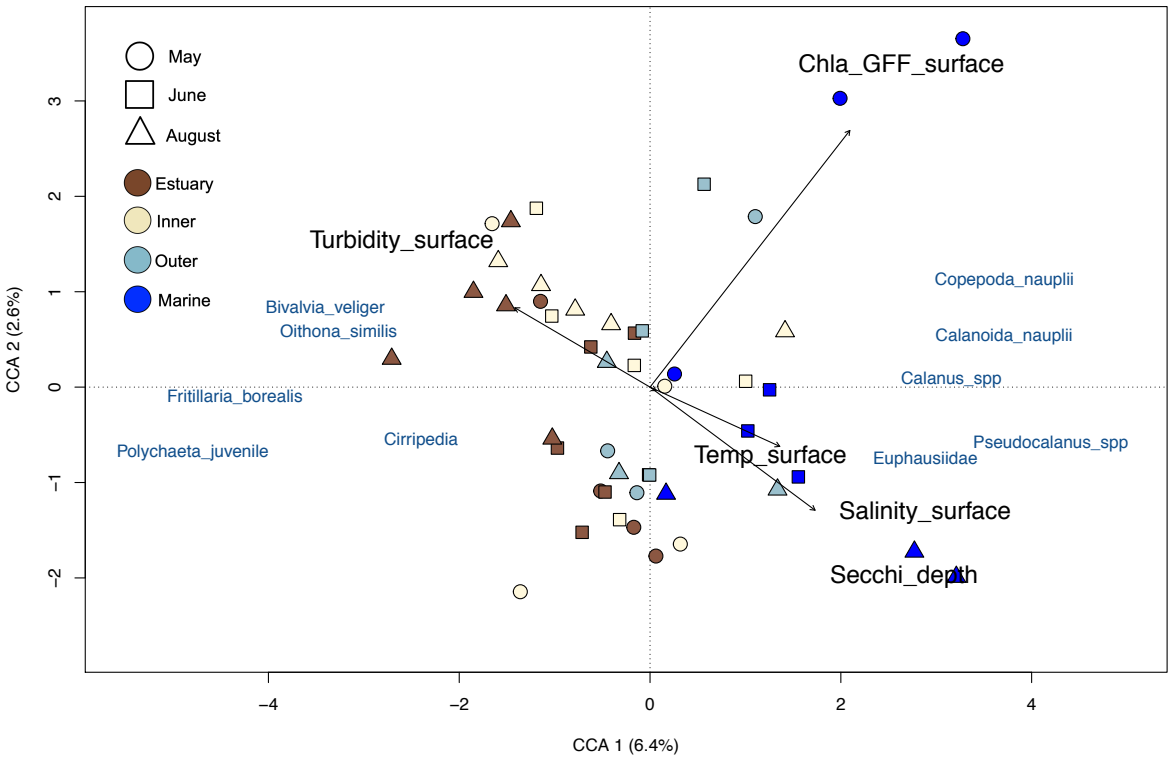

Figure 11: CCA diagram. CCA diagram showing community (individuals m^{-3}) data from May (circles), June (squares), and August (triangles), classified as estuary (brown), inner (white), outer (turquoise), and marine (blue) habitats. The variation is explained, excluding the variation explained by month and Julian day, but including surface environmental parameters (Chlorophyll *a*, Secchi depth, temperature, turbidity, and salinity). Zooplankton data is log-transformed (log (x+1)), environmental variables transformed as zero skewness. 30% of the most abundant (numerous) taxa are included in dark blue (bivalve veliger, Copepoda nauplii, *Pseudocalanus* spp., Calanoida nauplii, *Fritillaria borealis*, *Calanus* spp., *Oithona smilis*, Polychaeta juveniles, cirriped nauplii, euphausiid larvae), to show in which direction the taxa characterize the sites and environmental parameters.

sites are Secchi depth, salinity, and temperature, whereas the innermost sites are positively correlated with high turbidity. In the CCA excluding seasonality, only surface parameters are included, where Secchi depth and chlorophyll *a* are significant (Table 4). In the direction of the river estuary and inner sites, there is bivalve veliger, *O. similis*, *F. borealis,* and cirriped nauplii. In contrast, in the direction of the more marine sites, there are copepod nauplii, *Pseudocalanus* spp., *Calanus* spp., and euphausiids.

Table 4: Parameters in the CCA ordination analysis, their inertia (variation explained), the inertia proportion for each parameter, p-value, and significance. The data is from May, June, and August.

Parameter	**Depth**	**Inertia (variation explained) proportion**	**P-value**	**Significant (-/*)**
Month		0.33	0.001	*
Temperature (°C)	15 m	0.22	0.001	*
Temperature (°C)	Surface	0.21	0.001	*
Fjord		0.11	0.01	*
Type		0.1	0.01	*
Secchi depth (m)		0.1	0.001	*
Depth (m)		0.06	0.005	*
Salinity (PSU)	Surface	0.06	0.011	*
Salinity (PSU)	15 m	0.06	0.002	*
Turbidity (NTU)	15 m	0.04	0.054	-
Total chlorophyll a (ug/L)	Surface	0.04	0.069	-
Total chlorophyll a (ug/L)	15 m	0.04	0.071	-
Turbidity (NTU)	Surface	0.04	0.137	-
Total		1		

Table 5: Surface environmental parameters in the CCA ordination analysis excluding seasonal variation. Degrees of freedom, chi square, F and p-value of significance (* if significant) are shown.

	Df	**Chi square**	**F**	**p-value**	**Significant**
Secchi depth (m)	1	0.04303	2.5568	0.001	*
Total chlorophyll a (ug/L)	1	0.03566	2.1189	0.020	*
Temperature (°C)	1	0.01742	1.0350	0.412	
Turbidity (NTU)	1	0.02069	1.0350	0.412	
Salinity (PSU)	1	0.01484	0.8821	0.574	
Residual	35	0.55665			

4. Discussion

4.1 Terrestrial input

As expected, the terrestrial influence in Isfjorden increased as the snow and glacial melt season progressed with the freshest, warmest, and most turbid water found in August. Weaker, but distinct spatial patterns were also found with gradually less terrestrial influence from inner to the outer fjord sites, which is in accordance with previous studies (Lydersen et al. 2014; Carmack, Winsor, and Williams 2015; McGovern et al. 2019). Surface sea temperatures increased with increasing air temperatures (Appendix III). Particle input further accellerreted the temperatures since these dark particles efficiently absorb the solar irradiance. High input of particles also leads to high turbidity (Murray et al. 2015), which was clearly shown by the reduced Secchi depths. Despite expectations of lower chlorophyll *a* biomass in the innermost, most turbid sites, no clear spatial gradient was documented for chlorophyll *a*. However, the increase in total chlorophyll *a* along the fjordic gradient in May could indicate that the spring bloom started earlier in the innermost parts of the fjords prior to melting of the ice, followed by the outer sites, which had a still ongoing bloom during the sampling campaign in May. The low amount of nutrients at the innermost sites suggested that that the spring bloom had passed its peak, in contrast to the outer sites, where the nutrients were higher (McGovern et al., in prep.).

4.2 Zooplankton distribution along the land-sea gradient

4.2.1 Terrestrial impact on spatial patterns of zooplankton distribution

Species distribution

The most prominent spatial change of zooplankton species distribution along the salinity and turbidity gradient from inner to outer fjord habitats was related to the relative occurrence of meroplankton. Previous studies have shown clear spatial differences in zooplankton distribution related to environmental changes, such as glacial and riverine input (Tang et al. 2011; Arendt et al. 2016; Arimitsu, Piatt, and Mueter 2016). From glacial influenced fjords in the often very long and deep Greenland fjords, smaller copepod species such as *Microsetella* spp., *Pseudocalanus* spp. and *O. similis* have been characteristic of the inner part of the fjords near the glacial plumes, whereas *Calanus* spp. have been detected further out, in less turbid and

terrestrial influenced water (Tang et al. 2011; Arendt et al. 2016). In this study, the small copepod species, especially the cyclopoid copepod *O. similis*, were numerically important on all sites in all four habitats. These omnivorous copepods are cosmopolitans and are known to be tolerant to a wide range of salinities (Hansen et al. 2003; Walkusz et al. 2003; Ward and Hirst 2007), which could explain the similar abundances of *O. similis* throughout all the habitats in all months, especially in August. However, despite its suggested tolerance, *O. similis* may also be limited by temperature, and their development into more adult stages increases with higher temperatures (Ward and Hirst 2007). Billefjorden, a colder and more Arctic fjord enclosed by a sill, showed lower abundances than Adventfjorden and Tempelfjorden. This could suggest temperature to be a limiting factor in their distribution (Gluchowska et al. 2016). However, the lower abundance of *O. similis* could also be a direct result of less advection of water masses, due to the restricting sill in the fjord mouth.

Other small copepods, such as *Oncaea* spp., were only documented in the marine habitats. *Oncaea* spp. is often related to deeper water, which could explain their lack of presence in the shallower sites (Auel and Hagen 2002). In contrast, *Microcalanus* spp. was found in higher abundances at the marine endpoints but has, in previous studies, shown to be largely tolerant of physical changes in the environment (Hunt et al. 2014). Therefore, with an increase in terrestrial inputs, *Microcalanus* spp. may adapt and be more numerous at inner sites in the fjord. Studies have previously suggested that small copepods are often overlooked and thus underestimated in terms of their role as top-down grazers on algae or as prey for others when comparing with larger copepod species (Arendt et al. 2013; Tang et al. 2011; Turner 2004).

On a related note, one would expect to see higher abundances of larger copepods, especially *Calanus* spp., in the outermost habitats (Gluchowska et al. 2016; Stübner 2016). Gluchowska et al. 2016 (Gluchowska et al. 2016) documented advection of *Calanus* spp. from the outer shelf with currents into Isfjorden, moreover higher abundances than seen in this study. Also, previous studies have related *Calanus* spp. to the outer, less terrestrially influenced parts of glacial-fed fjord systems (Tang et al. 2011). The low abundances could be explained by migration to deeper water later in the season (Arendt et al. 2013), or interannual variation with lower abundances this specific year (Estrada et al. 2012; Hunt et al. 2014). *C. glacialis* has been documented to respond to hydrography in shallow areas and decrease with temperature and salinity (Daase et al. 2007). This could explain the low abundances of large copepods at the innermost sites, *Calanus* spp. in particular, considering the shallow sampling sites. However, a high occurrence of copepod nauplii was documented in the innermost sites in May. These high

abundances of herbivorous zooplankton could furthermore support the indication of an early onset spring bloom starting in the innermost part of the fjord, as described above.

In addition to copepods, other taxa have shown to be influenced by terrestrial input. From a study from a glacially influenced fjord in the Gulf of Alaska (Arimitsu, Piatt, and Mueter 2016), euphausiids increased in abundance with higher turbidity. A similar pattern was not detected in this study, even though higher abundances of euphausiids were documented in some of the inner sites in Tempelfjorden, which had higher turbidity. Moreover, ctenophores and other gelatinous species are shown to be highly tolerant to both changes in temperature and salinity (Purcell 2005). However, few gelatinous species were sampled in this study, and support other studies concluding that these gelatinous species are scarce in terrestrially influenced sites, such as glacial plumes (Balqis et al. 2019). Cnidarians and ctenophores are understudied, and the effects of terrestrial input in coastal ecosystems on these taxa are yet to be highlighted (Lucas et al. 2014) and should get more attention in future studies. Appendicularians, such as *Oikopleura* spp., and *F. borealis*, have previously been shown to have a high tolerance to low salinity (Estrada et al. 2012), where the latter species has been related to coastal areas, showing high abundances close to shore (Wyatt 1973). This, however, is not confirmed by this study where low abundances were seen throughout the months, and solely in outer habitats in May. These low abundances could be explained by local variations and, again, the advection of water masses (Basedow et al. 2004; Wassmann et al. 2015).

When comparing the zooplankton distribution along a gradient from inner to the outer fjord, it is also important to take into account the challenges coastal areas may include. The sampling sites included both very shallow sites (~8 m) and deeper sites (~250 m), which led to difficulties when comparing the zooplankton communities. It is important to point out that the abundance per cubic meter was chosen, rather than per square meter. Most zooplankton are found in the upper water column, hence depth stratified sampling would have been preferred and is recommended for similar future studies. Different ways to standardize the sampling sites were tested, e.g. only include the upper 50 meters or the calculated euphotic zone, but due to their vertical migration, a correction of the depth could potentially eliminate important data.

Size distribution

Freshwater input has previously shown to influence the copepod community composition, shifting from smaller to larger copepod species along a gradient from more freshwater input to less (Tang et al. 2011; Middelbo et al. 2018). Therefore, it was expected to see a more apparent shift in copepod sizes along a gradient from inner to outer habitats; however, a clear spatial

pattern was not detected. As mentioned earlier, the advection of water masses is an important factor (Gluchowska et al. 2016) and could influence the distribution of both smaller and larger sized copepods, in addition to younger copepodite stages (Mileikovsky 1968; Basedow et al. 2004). In fact, an increasing abundance of small copepods from the inner to outer parts of Isfjorden has previously been documented from Isfjorden (Gluchowska et al. 2016), which also highlights the dynamic system in Isfjorden. In addition, the effect glaciers have on zooplankton by entrapping them in deeper water layers due to system circulation, might also be influencing both smaller and larger copepods, leading to a less clear gradient from inner, glacial sites to outer sites (Lydersen et al. 2014).

It is also essential to emphasize that although this study expected differences along a gradient from inner to outer sites, all the included sites are a part of Isfjorden, which still is a fjord system, overall influenced by freshwater input (Nilsen et al. 2008). When comparing the marine endpoints in this study to actual open water stations, there are differences in both abundance and composition. E.g., the total abundance of zooplankton late in the summer was substantially higher than in open water north of Svalbard (Daase and Eiane 2007), especially in comparison with the innermost sites. Also, from the same study, even though some of the same species were abundant, such as *O. similis* and *Pseudocalanus* spp., species as *Microcalanus* spp. was highly abundant in open water. In this study, *Microcalanus* spp. were less abundant, even in the deeper marine endpoints. In addition, meso- and bathypelagic species have been documented with higher abundances in deeper, more open water, such as *Themisto libellula, T. abyssorum* and *Eukrohnia hamata*, in comparison with the marine endpoints in this study (Hop et al. 2006).

Zooplankton biomass and diversity

In addition to species and size distribution, species richness and diversity are essential factors in the Arctic marine ecosystem (Tittensor et al. 2010). It is commonly known that stress, e.g. environmental disturbance such as glacial or riverine input, may decrease both species richness and diversity (Witman et al. 2008; Estrada et al. 2012; Cauvy-Fraunié and Dangles 2019). This is further confirmed by differences shown in species diversity in exposed areas in comparison with sheltered areas (Scrosati et al. 2011). The clear changes in terrestrial input, as described earlier, would indicate more stress and thus an expectation of lower richness and diversity. Species diversity showed increasing changes along the gradient from the inner to the outer habitats, thus supporting previous research (Cauvy-Fraunié and Dangles 2019). This also concedes with Kosobokova et al. 2011 (Kosobokova, Hopcroft, and Hirche 2011), suggesting

that diversity increases with depth in the Arctic Ocean. For that reason, the increased species diversity could also be a result of increasing depth from inner to outer fjord. This would, however, be more evident with depth stratified sampling. Despite no significant differences between the months, a pattern of lower diversity was detected in August. This could be explained by the high dominance of *O. similis*, as the numerical dominance of smaller species may lower the diversity (Blachowiak-Samolyk et al. 2008; Estrada et al. 2012).

Glaciers are also known to lower the productivity in terms of abundance and biomass (Tittensor et al. 2010; Cauvy-Fraunié and Dangles 2019), where a negative impact has been documented on several groups of organisms in glacial-fed fjords (Estrada et al. 2012; Cauvy-Fraunié and Dangles 2019). Additionally, the biomass of zooplankton is lower in more stratified water in comparison with deeper, more well-mixed water (Estrada et al. 2012). The zooplankton biomass, however, did not show a clear increase along the gradient from inner to outer, in contrast to what was expected. In fact, the opposite trend was observed during the two first months, although, with no significant changes. This trend could be explained by a number of reasons. First of all, positive effects of glaciers have been reported, with the abundance of some taxa, e.g. with higher ability to specialize, have increased (Roman, Holliday, and Sanford 2001; Tang et al. 2011; Arendt et al. 2016). Similarly, zooplankton biomass has been documented to decrease with increasing distance to glaciers and river estuaries in fjord systems, which have been related to both temperature and advection of water masses (Lydersen et al. 2014; Arimitsu, Piatt, and Mueter 2016). Additionally, glacially fed fjords have shown to differ in effects; Arimitsu et al. 2016 (Arimitsu, Piatt, and Mueter 2016) observed the highest biomass of all zooplankton species combined near the glaciers in areas with great estuarine influence. In contrast, a negative impact was documented in a more oceanic study region. On a side note, as much as 50% of the total biomass may be based in the upper layers of the water column (Auel and Hagen 2002), which suggests that a different pattern would have detected solely looking at the upper water column. When seeing the biomass per square meter, the opposite pattern was seen in June and August, which adds further support to this.

It is also important to emphasize that this study did not separate the zooplankton groups when measuring biomass, which makes it challenging to compare to specific groups in other studies. Also, despite the low abundance, ctenophores and cnidarians were of practical reasons not included in the biomass but should be accounted for in future studies. Additionally, when looking at the high biomass at the marine sites in August in comparison with the similar abundance throughout the habitats, it could be suggested that some error has occurred when measuring the biomass from the marine sites.

Trophic mode

When looking at the dominant feeding modes of the zooplankton, a clear temporal shift was observed, but a spatial pattern was not. The seasonal pattern of herbivorous zooplankton dominance in May to omnivorous species dominance in August has also be seen in previous similar studies (Blachowiak-Samolyk et al. 2007) and is probably related to the shift from herbivorous cirriped nauplii in the spring to smaller omnivorous copepods. In comparison with the herbivorous and omnivorous species, the carnivorous species were outweighed in relative abundance. Their importance could also be more important after the summer months when most of the herbivores descend to deeper waters (Søreide et al. 2003). However, when looking only at the carnivores, some spatial patterns were detected. *P. elegans* mainly feed on copepods, which could explain the slight increase from river estuary sites to the outermost sites in June and August (Solov'ev and Kosobokova 2003). However, their abundance at the innermost sites in May could also confirm that they feed on smaller zooplankton, such as copepod nauplii and *Pseudocalanus* spp. (Falkenhaug 1991). Therefore, they may also take advantage of the high abundances of smaller zooplankton in the river estuaries early in the season. The gelatinous species *Mertensia ovum* is also observed in the estuaries later in the season. Even though the small copepods match with their preferential prey, *M. ovum* has also shown to feed on both bacterio- and microplankton (Majaneva et al. 2014), which could indicate they are grazing on that at the inner sites. Despite only a few individuals, these patterns could suggest that predators may take advantage of the available food at terrestrial influenced sites.

The herbivores and omnivores did, however, not show any distinct spatial patterns, despite a minor increase in abundance in June and August. As pointed out in the aims of this study, the expectations of a spatial gradient regarding trophic mode were challenged by a lack of similar, previous research. An explanation of this could be the lack of clear differentiation between the two trophic levels (Turner et al. 2001), which is also important to highlight when discussing zooplankton feeding preferences. Pure herbivorous or carnivorous species are rare amongst zooplankton and must be considered with caution (Mauchline et al. 1998; Blachowiak-Samolyk et al. 2007). Many of the species observed in this study are hard to distinguish when classifying feeding habits, and may also shift from one life stage to another (Nielsen 2018). Additionally, previous studies from Adventfjorden based on stable isotopes have suggested it to be hard to characterize zooplankton to trophic level in these waters, primarily because of the dynamic system (Carrasco et al. 2019). Also, the expected shift from omnivores to herbivores along the gradient was partly based on the expectation of decreased primary production in the innermost habitats, which was not seen clearly in this study.

4.2.2 Seasonal patterns

The seasonality in the Arctic is strong and influences the life cycles and strategies of the zooplankton (Michelsen et al. 2017; Weydmann et al. 2013). This study documented a strong seasonality in relation to the contribution of meroplankton. However, when looking at holoplankton separately, some clear seasonal patterns were also detected. The abundance in May was dominated by copepod nauplii, which continued with earlier stages of *Calanus* spp. in June. These patterns support previous research (Hop et al. 2006; Weydmann et al. 2013), where larger copepods, such as *Calanus* spp. adults, ascend from the deeper water layers in timing with spring bloom for hatching (Daase et al. 2013). In August, however, the large fraction of smaller sized copepods relative to larger sized species is unexpected (Gluchowska et al. 2016). Small copepods often increase in abundance later in the summer, and their dominance has been documented earlier in the Arctic (Hop et al. 2006; Svensen et al. 2011). Nevertheless, it would be expected to see a more substantial fraction of large adult copepods at this time of the year, especially *Calanus* spp., furthermore a evener balance between small and large copepods (Gluchowska et al. 2016). One explanation to this pattern could be a migration of larger sized copepods to deeper water, which may also support the large fraction of small copepods as they may follow this migration, and occupy the upper, more productive water layer (Arendt et al. 2013). Also, the copepodite stages of *C. finmarchicus* (<CIV) may stay in the surface until the end of August due to timing of reproduction, which is longer than the more arctic species *C. glacialis,* and could explain the relative abundance of copepodites relative to adult copepods (Weydmann et al. 2013).

4.2.3 Meroplankton

Meroplankton is a group of plankton with high seasonal variability, as they mainly comprise of larval stages that disappear from the water column once their development towards settlement and further development to adulthood is moving on (Stübner et al. 2016). Previous studies have documented that tidal currents may favor and lead to an accumulation of meroplankton near river plumes (Ayata et al. 2011), also, to enhance their survival through nutrient input (Fetzer and Arntz 2008). A spatial pattern of decreasing meroplankton and increasing holoplankton along a salinity gradient from inner to outer was detected in May and especially in June. Even though many studies have been focusing on the comparison of shelf areas and deeper oceanic waters, benthic larvae have shown also to be more abundant close to shore rather than in open fjord (Fetzer 2003; Hop et al. 2019). Moreover, the contribution of meroplankton to the total

zooplankton community and their abundances may be higher in estuaries and inlets (Kulikova, Solokhina, and Samatov 2000; Fetzer 2003).

Several studies have shown that an estuarine turbidity maximum, enforced by the estuarine circulation, may act as an entrapment zone for zooplankton, in particular for smaller species, such as meroplankton and smaller copepods (Crump and Baross 1996; Roman, Holliday, and Sanford 2001). These entrapment zones lead to less risk of predation due to high turbidity, and opportunities of bacterial grazing (Roman, Holliday, and Sanford 2001). The high abundances of cirriped nauplii and cypris at the river estuary habitats could be explained by this feature. The entrapment zones could also explain the higher abundances of polychaete larvae in the river estuaries. Moreover, that may lead to further accumulation and up-concentration of their offspring, leading to them to inhabit estuaries (Kuklinski et al. 2013). It is also important to emphasize the dynamic of the river and glacier plumes and note that many of the sampling sites were influenced by a clear distinction between highly turbid water in comparison with clearer, less turbid water. These high turbidity water masses may change rapidly. Thus, even though a clear pattern was seen along the gradient from inner to outer, one must take into account the local changes, that may change from one day to another and from one tidewater cycle to the other with wind direction. As described earlier, meroplankton may be less influenced by the advection of water masses, due to their short period in the pelagic, thus being more dependent on the local environment (Mileikovsky, 1968). This could also explain the dominance of meroplankton in relation to holoplankton, as a result of holoplankton being more affected than meroplankton. Also, the clogging of the net by *Phaeocystis* spp. in May, may have resulted in data not being evident. From personal observations, these samples were rich with cirriped nauplii, which were not clearly reflected in the sample analysis.

Arctic meroplankton is known to have strong seasonal pulses, with blooms in the most productive season around spring and summer, dominating the zooplankton community in both biomass and abundance (Gluchowska et al. 2016; Stübner et al. 2016). This is in accordance with this study, which shows a clear peak of meroplankton early in the season, but earlier than seen in previous studies (Stübner et al. 2016; Brandner et al. 2017), with the highest abundances in July. Meroplankton are associated with temperature and chlorophyll *a* (Michelsen et al. 2017), which could explain the considerable high abundance in spring, given that the spring bloom may have started earlier than in previous studies, as described earlier. The low abundances of meroplankton in August were unexpected when looking at previous research from the same area (Stübner et al. 2016). However, this could be explained by the narrow

window of meroplankton occurrence in the water column (Gluchowska et al. 2016); thus, the abundance is lower at the end of the season in comparison with earlier in the season.

Despite the lower abundances later in the season, there was a clear seasonal shift in the species composition from May to August, which also has been shown in previous studies (Meerhoff, Tapia, and Castro 2014; Stübner et al. 2016; Michelsen et al. 2017). The dominance of cirriped nauplii and cypris earlier in the productive season relative to bivalve veliger could be explained by the benthic community in Isfjorden, in particular at the inner sites, and again; the advection of water masses into the fjord system (Gluchowska et al. 2016). In addition, bivalve veliger has shown to be associated with warmer water, in contrast to barnacle larvae, which are related to colder water and chlorophyll *a* concentration (Meerhoff, Tapia, and Castro 2014). This could explain the seasonal shift, moreover, the increase of bivalve veliger from inner to outer sites in June, and August, as the temperatures rise throughout the season.

4.3 Terrestrial influence and drivers

The findings of this study agree with those previous that have documented a terrestrial influence on the spatial distribution of the zooplankton communities (Tang et al. 2011; Arimitsu, Piatt, and Mueter 2016; Middelbo et al. 2018). Zooplankton communities are influenced by the physical properties of the water masses surrounding them (Kaiser et al. 2011). Salinity is an important driver and a potential limiting factor for zooplankton (Toumi et al. 2005), as well as temperature (O'Connor et al. 2007; Meerhoff, Tapia, and Castro 2014). In addition, both food availability and predation pressure play an essential role, which both are also affected by salinity and temperature (Meerhoff, Tapia, and Castro 2014). In addition to the more globally known parameters, more area-dependent factors may also play a role, such as sea-ice thickness (Weydmann et al. 2013). In this study, seasonality, which correlates highly with temperature, explained most of the variation, followed by light conditions, salinity, and chlorophyll *a*. Clear spatial patterns were shown in the physical parameters. Thus, it was expected that the zooplankton communities changed accordingly. Together with the physical and environmental parameters that changed throughout the season, the habitat categories explained some variation, which was further confirmed when excluding the parameters directly linked to seasonality, such as Julian day and month. This is in accordance with a number of papers that have detected changes in both the primary and secondary production due to terrestrial input (Arimitsu, Piatt, and Mueter 2016; Middelbo et al. 2018). However, it is essential to take into account that many of the parameters showing spatial patterns along the gradient from inner to outer, also vary with

the season. It is challenging to separate the seasonality from the spatial gradient, nor the other way around. However, this study documents that both temperature, light conditions, and salinity are significant factors explaining the zooplankton communities, which are related to seasonality, but also terrestrial input.

Nonetheless, it is also important to emphasize the residual variation not explained by the measured parameters, which are most likely explained by parameters not included in this study. One of the most important factors concerning zooplankton dynamics is the advection of water masses and water mass properties (Estrada et al. 2012; Gluchowska et al. 2016). Even though physical parameters were included, measures of water mass advection would give a better understanding of how the zooplankton communities are influenced. Several studies from Arctic fjord systems have shown that despite terrestrial influence, advection is a key determinantal driver (Arimitsu, Piatt, and Mueter 2016; Gluchowska et al. 2016; Michelsen et al. 2017).

4.4 Concluding remarks

This thesis aimed to investigate the influence of terrestrial input on zooplankton communities along a gradient from inner to open fjord. By analyzing the environmental physical and biological parameters, and the zooplankton abundance, biomass and, diversity, the following concluding remarks were drawn.

1. The most important driver of the zooplankton communities, and the factor explaining most of the variation, was the seasonality. Both holoplankton and meroplankton showed clear seasonal patterns, shifting from mainly copepod nauplii and cirriped nauplii in May to *O. similis* and bivalve veliger in August. A distinct change in the size distribution of copepods was not detected spatially. Smaller sized copepods, mainly *O. similis,* were present in all habitats in all months and dominated across all habitats in August. This suggests zooplankton communities to be driven by life-history traits (e.g. reproduction and seasonal migration), which again explain the high percentage explained by season. Spatial zooplankton patterns were much weaker but distinct. The most prominent spatial pattern was the high relative contribution of meroplankton to the overall zooplankton community at the innermost sites.

2. A distinct spatial gradient in feeding preferences was not found from inner to outermost sites. However, a clear seasonal pattern was detected, shifting from predominantly herbivores in May, to omnivores in August. The thesis also highlighted the difficulties with classifying zooplankton feeding preferences correctly.

3. The zooplankton biomass did not change between months, nor between habitats. The species diversity, however, showed a gradual increase from the innermost to the outer habitats in all months. Some taxa, such as *Oncaea* spp., for instance, was only found at the marine endpoints, which suggests that other taxa, e.g. *O. similis*, found everywhere, to be more tolerant than other copepod species to differences in the physical environment.

All in all, this study supports that terrestrial input has an impact on the zooplankton communities, in accordance with previous research. Seasonality, correlated with temperature, explained a considerable fraction of the variation, followed by light conditions, and salinity. When eliminating the parameters directly associated with seasonality, chlorophyll *a* was also an important driver.

With continuing rising temperatures leading to increased terrestrial riverine inputs, it is highly recommended with more research on the impact of terrestrial input on coastal ecosystems. This study of zooplankton community structures, biomass, diversity, and feeding mode in Arctic coastal areas provide important baseline information to enable us to follow the ongoing changes in Arctic fjords. In order to gain more knowledge, more detailed zooplankton identification is needed, including genetic analysis and a more precise understanding of the water mass circulation.

References

Adakudlu, M, J Andresen, J Bakke, S Beldring, R Benestad, W Bilt, J Bogen, et al. 2019. "Climate in Svalbard 2100."

Arendt, Kristine Engel, Mette Dalgaard Agersted, Mikael Kristian Sejr, and Thomas Juul-Pedersen. 2016. "Glacial Meltwater Influences on Plankton Community Structure and the Importance of Top-down Control (of Primary Production) in a NE Greenland Fjord." *Estuarine, Coastal and Shelf Science* 183: 123–35. https://doi.org/10.1016/j.ecss.2016.08.026.

Arendt, Kristine Engel, Thomas Juul-Pedersen, John Mortensen, Martin Emil Blicher, and Søren Rysgaard. 2013. "A 5-Year Study of Seasonal Patterns in Mesozooplankton Community Structure in a Sub-Arctic Fjord Reveals Dominance of Microsetella Norvegica (Crustacea, Copepoda)." *Journal of Plankton Research* 35 (1): 105–20. https://doi.org/10.1093/plankt/fbs087.

Arimitsu, Mayumi L., John F. Piatt, and Franz Mueter. 2016. "Influence of Glacier Runoff on Ecosystem Structure in Gulf of Alaska Fjords." *Marine Ecology Progress Series* 560: 19–40. https://doi.org/10.3354/meps11888.

Auel, H., and W. Hagen. 2002. "Mesozooplankton Community Structure, Abundance and Biomass in the Central Arctic Ocean." *Marine Biology* 140 (5): 1013–21. https://doi.org/10.1007/s00227-001-0775-4.

Ayata, Sakina Dorothée, Robin Stolba, Thierry Comtet, and Éric Thiébaut. 2011. "Meroplankton Distribution and Its Relationship to Coastal Mesoscale Hydrological Structure in the Northern Bay of Biscay (NE Atlantic)." *Journal of Plankton Research*. https://doi.org/10.1093/plankt/fbr030.

Balqis, Siti A.R., Fatimah Md Yusoff, Jun Nishikawa, Dhugal Lindsay, and Shuhei Nishida. 2019. "Influence of Environmental Parameters on Habitat Preference of Gelatinous Zooplankton in Various Coastal Ecosystems, the Straits of Malacca." *Regional Studies in Marine Science*. https://doi.org/10.1016/j.rsma.2019.100712.

Basedow, Sünnje L., Ketil Eiane, Vigdis Tverberg, and Michael Spindler. 2004. "Advection of Zooplankton in an Arctic Fjord (Kongsfjorden, Svalbard)." *Estuarine, Coastal and Shelf Science*. https://doi.org/10.1016/j.ecss.2003.12.004.

Blachowiak-Samolyk, Katarzyna, Slawek Kwasniewski, Katarzyna Dmoch, Haakon Hop, and Stig Falk-Petersen. 2007. "Trophic Structure of Zooplankton in the Fram Strait in Spring

and Autumn 2003." *Deep-Sea Research Part II: Topical Studies in Oceanography* 54 (23–26): 2716–28. https://doi.org/10.1016/j.dsr2.2007.08.004.

Blachowiak-Samolyk, Katarzyna, Janne E. Søreide, Slawek Kwasniewski, Arild Sundfjord, Haakon Hop, Stig Falk-Petersen, and Else Nøst Hegseth. 2008. "Hydrodynamic Control of Mesozooplankton Abundance and Biomass in Northern Svalbard Waters (79-81°N)." *Deep-Sea Research Part II: Topical Studies in Oceanography* 55 (20–21): 2210–24. https://doi.org/10.1016/j.dsr2.2008.05.018.

Braak, Cajo J F ter. 1986. "Canonical Correspondence Analysis: A New Eigenvector Technique for Multivariate Direct Gradient Analysis." *Ecology* 67 (5): 1167–79. https://doi.org/10.2307/1938672.

Brandner, Melissa M., Eike Stübner, Adam J. Reed, Tove M. Gabrielsen, and Sven Thatje. 2017. "Seasonality of Bivalve Larvae within a High Arctic Fjord." *Polar Biology* 40 (2): 263–76. https://doi.org/10.1007/s00300-016-1950-x.

Calleja, Maria Ll, P. Kerhervé, S. Bourgeois, M. Kędra, A. Leynaert, E. Devred, M. Babin, and N. Morata. 2017. "Effects of Increase Glacier Discharge on Phytoplankton Bloom Dynamics and Pelagic Geochemistry in a High Arctic Fjord." *Progress in Oceanography* 159 (July): 195–210. https://doi.org/10.1016/j.pocean.2017.07.005.

Cape, Mattias, Fiamma Straneo, Nicholas Beaird, Randelle Bundy, and Matthew Charette. 2019. "Nutrient Release to Oceans from Buoyancy-Driven Upwelling at Greenland Tidewater Glaciers." *Nature Geoscience* 12 (January). https://doi.org/10.1038/s41561-018-0268-4.

Carmack, Eddy, Peter Winsor, and William Williams. 2015. "The Contiguous Panarctic Riverine Coastal Domain: A Unifying Concept." *Progress in Oceanography* 139: 13–23. https://doi.org/10.1016/j.pocean.2015.07.014.

Carrasco, N, Amanda Poste, Anita Evenset, J. E. Søreide, and Maeve McGovern. 2019. "Seasonality in Mercury Bioaccumulation in Particulate Organic Matter and Zooplankton in a River-Influenced Arctic Fjord (Adventfjord, Svalbard)." University of Tromsø.

Cauvy-Fraunié, Sophie, and Olivier Dangles. 2019. "A Global Synthesis of Biodiversity Responses to Glacier Retreat." *Nature Ecology & Evolution*. https://doi.org/10.1038/s41559-019-1042-8.

Chen, Mianrun, Hongbin Liu, and Bingzhang Chen. 2017. "Seasonal Variability of Mesozooplankton Feeding Rates on Phytoplankton in Subtropical Coastal and Estuarine Waters." *Frontiers in Marine Science*. https://doi.org/10.3389/fmars.2017.00186.

Clarke, K, and Richard Warwick. 2001. “Clarke KR, Warwick RM.Change in Marine Communities: An Approach to Statistical Analysis and Interpretation. Primer-E Ltd: Plymouth, UK.” In .

Cloern, J. E., S. Q. Foster, and A. E. Kleckner. 2014. “Phytoplankton Primary Production in the World’s Estuarine-Coastal Ecosystems.” *Biogeosciences*. https://doi.org/10.5194/bg-11-2477-2014.

Correa-Metrio, Alex, Yanus Dechnik, Socorro Lozano, and Margarita Caballero. 2013. “Detrended Correspondence Analysis: A Useful Tool to Quantify Ecological Changes from Fossil Data Sets.” *Boletín de La Sociedad Geológica Mexicana* 66: 135–43. https://doi.org/10.18268/BSGM2014v66n1a10.

Cottier, F. R., F. Nilsen, M. E. Enall, S. Gerland, V. Tverberg, and H. Svendsen. 2007. “Wintertime Warming of an Arctic Shelf in Response to Large-Scale Atmospheric Circulation.” *Geophysical Research Letters*. https://doi.org/10.1029/2007GL029948.

Crump, Byron C., and John A. Baross. 1996. “Particle-Attached Bacteria and Heterotrophic Plankton Associated with the Columbia River Estuarine Turbidity Maxima.” *Marine Ecology Progress Series*. https://doi.org/10.3354/meps138265.

Daase, Malin, and Ketil Eiane. 2007. “Mesozooplankton Distribution in Northern Svalbard Waters in Relation to Hydrography.” *Polar Biology* 30 (8): 969–81. https://doi.org/10.1007/s00300-007-0255-5.

Daase, Malin, Stig Falk-Petersen, Øystein Varpe, Gerald Darnis, Janne E. Søreide, Anette Wold, Eva Leu, Jørgen Berge, Benoit Philippe, and Louis Fortier. 2013. “Timing of Reproductive Events in the Marine Copepod Calanus Glacialis: A Pan-Arctic Perspective.” *Canadian Journal of Fisheries and Aquatic Sciences*. https://doi.org/10.1139/cjfas-2012-0401.

Daase, Malin, Jon Olav Vik, Espen Bagøien, Nils Christian Stenseth, and Ketil Eiane. 2007. “The Influence of Advection on Calanus near Svalbard: Statistical Relations between Salinity, Temperature and Copepod Abundance.” *Journal of Plankton Research* 29 (10): 903–11. https://doi.org/10.1093/plankt/fbm068.

Estrada, Rafael, Michel Harvey, Michel Gosselin, Michel Starr, Peter S. Galbraith, and Fiammetta Straneo. 2012. “Late-Summer Zooplankton Community Structure, Abundance, and Distribution in the Hudson Bay System (Canada) and Their Relationships with Environmental Conditions, 2003-2006.” *Progress in Oceanography* 101 (1): 121–45. https://doi.org/10.1016/j.pocean.2012.02.003.

Falk-Petersen, Stig, Christopher Hopkins, and J R Sargent. 1990. “Trophic Relationships in

the Pelagic, Arctic Food Web." *Trophic Relationships in the Marine Environment*, 315–33.

Falkenhaug, Tone. 1991. "Prey Composition and Feeding Rate of Sagitta Elegans Var. Arctica (Chaetognatha) in the Barents Sea in Early Summer." *Polar Research*. https://doi.org/10.3402/polar.v10i2.6761.

Fetzer, Ingo. 2003. "Distribution of Meroplankton in the Southern Kara Sea in Relation to Local Hydrographic Pattern." *Proc. Mar. Sci.* 6. https://doi.org/10.1016/S1568-2692(03)80038-4.

Fetzer, Ingo, and Wolf E. Arntz. 2008. "Reproductive Strategies of Benthic Invertebrates in the Kara Sea (Russian Arctic): Adaptation of Reproduction Modes to Cold Water." *Marine Ecology Progress Series*. https://doi.org/10.3354/meps07271.

Flink, Anne Elina, Riko Noormets, Nina Kirchner, Douglas I. Benn, Adrian Luckman, and Harold Lovell. 2015. "The Evolution of a Submarine Landform Record Following Recent and Multiple Surges of Tunabreen Glacier, Svalbard." *Quaternary Science Reviews* 108: 37–50. https://doi.org/10.1016/j.quascirev.2014.11.006.

Forwick, Matthias, Nicole J. Baeten, and Tore O. Vorren. 2009. "Pockmarks in Spitsbergen Fjords." *Norsk Geologisk Tidsskrift* 89 (1–2): 65–77.

Forwick, Matthias, Tore O. Vorren, Morten Hald, Sergei Korsun, Yul Roh, Christoph Vogt, and Kyu Cheul Yoo. 2010. "Spatial and Temporal Influence of Glaciers and Rivers on the Sedimentary Environment in Sassenfjorden and Tempelfjorden, Spitsbergen." *Geological Society Special Publication* 344 (October 2014): 163–93. https://doi.org/10.1144/SP344.13.

Gluchowska, Marta, Slawomir Kwasniewski, Agnieszka Prominska, Anna Olszewska, Ilona Goszczko, Stig Falk-Petersen, Haakon Hop, and Jan Marcin Weslawski. 2016. "Zooplankton in Svalbard Fjords on the Atlantic–Arctic Boundary." *Polar Biology* 39 (10): 1785–1802. https://doi.org/10.1007/s00300-016-1991-1.

Goral, Friedemann, and Jenny Schellenberg. 2018. "Goeveg: Functions for Community Data and Ordinations." https://cran.r-project.org/package=goeveg.

Grebmeier, Jacqueline M., Lee W. Cooper, Howard M. Feder, and Boris I. Sirenko. 2006. "Ecosystem Dynamics of the Pacific-Influenced Northern Bering and Chukchi Seas in the Amerasian Arctic." *Progress in Oceanography* 71 (2–4): 331–61. https://doi.org/10.1016/j.pocean.2006.10.001.

Hagen, Jon, Kjetil Melvold, Francis Pinglot, and Julian Dowdeswell. 2003. "On the Net Mass Balance of the Glaciers and Ice Caps in Svalbard, Norwegian Arctic." *Arctic Antarctic*

and Alpine Research - ARCT ANTARCT ALP RES 35 (May): 264–70. https://doi.org/10.1657/1523-0430(2003)035[0264:OTNMBO]2.0.CO;2.

Hansen, Anja Skjoldborg, Torkel Gissel Nielsen, Henrik Levinsen, Siz D. Madsen, T. Frede Thingstad, and Benni Winding Hansen. 2003. "Impact of Changing Ice Cover on Pelagic Productivity and Food Web Structure in Disko Bay, West Greenland: A Dynamic Model Approach." *Deep-Sea Research Part I: Oceanographic Research Papers*. https://doi.org/10.1016/S0967-0637(02)00133-4.

Harvey, M. 2001. "Hydrodynamic Control of Late Summer Species Composition and Abundance of Zooplankton in Hudson Bay and Hudson Strait (Canada)." *Journal of Plankton Research*. https://doi.org/10.1093/plankt/23.5.481.

Hays, Graeme C. 2003. "A Review of the Adaptive Significance and Ecosystem Consequences of Zooplankton Diel Vertical Migrations." In *Hydrobiologia*. https://doi.org/10.1023/B:HYDR.0000008476.23617.b0.

Hensen, V. 1887. "Über Die Bestimmung Des Planktons Oder Des Im Meere Treibenden Materials an Pflanzen Und Tieren. Fünfter Ber. d. Komm, Zur Wiss." *Unters. Deutsch. Meere i. Kiel (18852—1886). Berlin*, 67.

Hill, M O, and H G Gauch. 1980. "Detrended Correspondence Analysis: An Improved Ordination Technique." *Vegetatio* 42 (1/3): 47–58. http://www.jstor.org/stable/20145789.

Holding, Johnna M., Stiig Markager, Thomas Juul-Pedersen, Maria L. Paulsen, Eva F. Møller, Lorenz Meire, and Mikael K. Sejr. 2019. "Seasonal and Spatial Patterns of Primary Production in a High-Latitude Fjord Affected by Greenland Ice Sheet Run-Off." *Biogeosciences Discussions*. https://doi.org/10.5194/bg-2019-203.

Hop, Haakon, Philipp Assmy, Anette Wold, Arild Sundfjord, Malin Daase, Pedro Duarte, Slawomir Kwasniewski, et al. 2019. "Pelagic Ecosystem Characteristics across the Atlantic Water Boundary Current from Rijpfjorden, Svalbard, to the Arctic Ocean during Summer (2010-2014)." *Frontiers in Marine Science* 6 (APR): 1–21. https://doi.org/10.3389/fmars.2019.00181.

Hop, Haakon, Stig Falk-Petersen, Harald Svendsen, Slawek Kwasniewski, Vladimir Pavlov, Olga Pavlova, and Janne E. Søreide. 2006. "Physical and Biological Characteristics of the Pelagic System across Fram Strait to Kongsfjorden." *Progress in Oceanography*. https://doi.org/10.1016/j.pocean.2006.09.007.

Hopwood, Mark J., Dustin Carroll, Thorben Dunse, Andy Hodson, Johnna M. Holding, José L. Iriarte, Sofia Ribeiro, et al. 2019. "Review Article: How Does Glacier Discharge

Affect Marine Biogeochemistry and Primary Production in the Arctic?" *The Cryosphere Discussions*. https://doi.org/10.5194/tc-2019-136.

Horton, T, A Kroh, S Ahyong, N Bailly, C B Boyko, S N Brandão, S Gofas, et al. 2019. "World Register of Marine Species (WoRMS)." WoRMS Editorial Board. http://www.marinespecies.org.

Humlum, Ole, Arne Instanes, and Johan Ludvig Sollid. 2003. "Permafrost in Svalbard: A Review of Research History, Climatic Background and Engineering Challenges." *Polar Research*. https://doi.org/10.3402/polar.v22i2.6455.

Hunt, Brian P.V., R. John Nelson, Bill Williams, Fiona A. McLaughlin, Kelly V. Young, Kristina A. Brown, Svein Vagle, and Eddy C. Carmack. 2014. "Zooplankton Community Structure and Dynamics in the Arctic Canada Basin during a Period of Intense Environmental Change (2004-2009)." *Journal of Geophysical Research: Oceans* 119 (4): 2518–38. https://doi.org/10.1002/2013JC009156.

Juul-Pedersen, Thomas, Kristine E. Arendt, John Mortensen, Martin E. Blicher, Dorte H. Søgaard, and Søren Rysgaard. 2015. "Seasonal and Interannual Phytoplankton Production in a Sub-Arctic Tidewater Outlet Glacier Fjord, SW Greenland." *Marine Ecology Progress Series* 524 (March): 27–38. https://doi.org/10.3354/meps11174.

Kahru, Mati, Zhongping Lee, B Greg Mitchell, and Cynthia D Nevison. 2016. "Effects of Sea Ice Cover on Satellite-Detected Primary Production in the Arctic Ocean." *Biology Letters* 12 (11): 20160223. https://doi.org/10.1098/rsbl.2016.0223.

Kaiser, Michel, Martin Attrill, Simon Jennings, David Thomas, D Barnes, Andrew Brierley, Jan Hiddink, Hermanni Kaartokallio, Nicholas Polunin, and D Raffaelli. 2011. *Marine Ecology: Processes, Systems and Impacts*.

Kosobokova, Ksenia N., Russell R. Hopcroft, and Hans Jürgen Hirche. 2011. "Patterns of Zooplankton Diversity through the Depths of the Arctic's Central Basins." *Marine Biodiversity* 41 (1): 29–50. https://doi.org/10.1007/s12526-010-0057-9.

Kraberg, Alexandra, Marcus Baumann, and Claus.-Dieter Dürselen. 2010. *Coastal Phytoplankton: Photo Guide for Northern European Seas*. *Verlag Dr. Friedrich Pfeil.*

Kuklinski, Piotr, Jørgen Berge, Laurel McFadden, Katarzyna Dmoch, Marek Zajaczkowski, Henrik Nygård, Kasia Piwosz, and Agnieszka Tatarek. 2013. "Seasonality of Occurrence and Recruitment of Arctic Marine Benthic Invertebrate Larvae in Relation to Environmental Variables." *Polar Biology*. https://doi.org/10.1007/s00300-012-1283-3.

Kulikova, V A, E V Solokhina, and A D Samatov. 2000. "Meroplankton of Avachinskii Inlet (Kamchatka)." *Russian Journal of Marine Biology* 26 (1): 1–7.

https://doi.org/10.1007/BF02759486.

Kwasniewski, Slawomir, Marta Gluchowska, Dariusz Jakubas, Katarzyna Wojczulanis-Jakubas, Wojciech Walkusz, Nina Karnovsky, Katarzyna Blachowiak-Samolyk, Malgorzata Cisek, and Lech Stempniewicz. 2010. "The Impact of Different Hydrographic Conditions and Zooplankton Communities on Provisioning Little Auks along the West Coast of Spitsbergen." *Progress in Oceanography* 87 (1–4): 72–82. https://doi.org/10.1016/j.pocean.2010.06.004.

Leu, E., J. E. Søreide, D. O. Hessen, S. Falk-Petersen, and J. Berge. 2011. "Consequences of Changing Sea-Ice Cover for Primary and Secondary Producers in the European Arctic Shelf Seas: Timing, Quantity, and Quality." *Progress in Oceanography* 90 (1–4): 18–32. https://doi.org/10.1016/j.pocean.2011.02.004.

Li, William K.W., Fiona A. McLaughlin, Connie Lovejoy, and Eddy C. Carmack. 2009. "Smallest Algae Thrive as the Arctic Ocean Freshens." *Science* 326 (5952): 539. https://doi.org/10.1126/science.1179798.

Lucas, Cathy H., Daniel O.B. Jones, Catherine J. Hollyhead, Robert H. Condon, Carlos M. Duarte, William M. Graham, Kelly L. Robinson, Kylie A. Pitt, Mark Schildhauer, and Jim Regetz. 2014. "Gelatinous Zooplankton Biomass in the Global Oceans: Geographic Variation and Environmental Drivers." *Global Ecology and Biogeography*. https://doi.org/10.1111/geb.12169.

Lunt, Jessica, and Delbert L. Smee. 2015. "Turbidity Interferes with Foraging Success of Visual but Not Chemosensory Predators." *PeerJ*. https://doi.org/10.7717/peerj.1212.

Lydersen, Christian, Philipp Assmy, Stig Falk-Petersen, Jack Kohler, Kit M. Kovacs, Marit Reigstad, Harald Steen, et al. 2014. "The Importance of Tidewater Glaciers for Marine Mammals and Seabirds in Svalbard, Norway." *Journal of Marine Systems*. https://doi.org/10.1016/j.jmarsys.2013.09.006.

Majaneva, Sanna, Outi Setälä, Elena Gorokhova, and Maiju Lehtiniemi. 2014. "Feeding of the Arctic Ctenophore Mertensia Ovum in the Baltic Sea: Evidence of the Use of Microbial Prey." *Journal of Plankton Research*. https://doi.org/10.1093/plankt/fbt101.

Mauchline, J., J. H.S. Blaxter, A. J. Southward, and P. A. Tyler. 1998. "The Biology of Calanoid Copepods." *Advances in Marine Biology*.

McGovern, M, A Pavlov, J. E. Søreide, E. Leu, and Amanda Poste. n.d. "Physicochemical Response to Terrestrial Inputs in a River and Glacier-Influenced Arctic Fjord System (Isfjorden, Svalbard)." *Frontiers of Marine Science*.

McGovern, Maeve, Anita Evenset, Katrine Borgå, Heleen A. De Wit, Hans Fredrik Veiteberg

Braaten, Dag Olav Hessen, Sabrina Schultze, Anders Ruus, and Amanda Poste. 2019. "Implications of Coastal Darkening for Contaminant Transport, Bioavailability, and Trophic Transfer in Northern Coastal Waters." *Environmental Science and Technology*. https://doi.org/10.1021/acs.est.9b03093.

Meerhoff, Erika, Fabián J Tapia, and Leonardo R Castro. 2014. "Spatial Structure of the Meroplankton Community along a Patagonian Fjord – The Role of Changing Freshwater Inputs." *Progress in Oceanography* 129: 125–35. https://doi.org/https://doi.org/10.1016/j.pocean.2014.05.015.

Meire, Lorenz, John Mortensen, Patrick Meire, Thomas Juul-Pedersen, Mikael K. Sejr, Søren Rysgaard, Rasmus Nygaard, Philippe Huybrechts, and Filip J.R. Meysman. 2017. "Marine-Terminating Glaciers Sustain High Productivity in Greenland Fjords." *Global Change Biology*. https://doi.org/10.1111/gcb.13801.

Michelsen, Helena Kling, Camilla Svensen, Marit Reigstad, Einar Magnus Nilssen, and Torstein Pedersen. 2017. "Seasonal Dynamics of Meroplankton in a High-Latitude Fjord." *Journal of Marine Systems* 168: 17–30. https://doi.org/10.1016/j.jmarsys.2016.12.001.

Middelbo, Ane Bruun, Mikael Kristian Sejr, Kristine Engel Arendt, and Eva Friis Møller. 2018. "Impact of Glacial Meltwater on Spatiotemporal Distribution of Copepods and Their Grazing Impact in Young Sound NE, Greenland." *Limnology and Oceanography* 63 (1): 322–36. https://doi.org/10.1002/lno.10633.

Mileikovsky, S A. 1968. "Distribution of Pelagic Larvae of Bottom Invertebrates of the Norwegian and Barents Seas." *Marine Biology* 1 (3): 161–67. https://doi.org/10.1007/BF00347105.

Muckenhuber, Stefan, Frank Nilsen, Anton Korosov, and S Sandven. 2016. "Sea Ice Cover in Isfjorden and Hornsund, Svalbard (2000–2014) from Remote Sensing Data." *The Cryosphere* 10: 149–58. https://doi.org/10.5194/tc-10-149-2016.

Munk, Peter, Torkel Gissel Nielsen, and Benni Winding Hansen. 2014. "Horizontal and Vertical Dynamics of Zooplankton and Larval Fish Communities during Mid-Summer in Disko Bay, West Greenland." *Journal of Plankton Research*. https://doi.org/10.1093/plankt/fbv034.

Murray, Ciarán, Stiig Markager, Colin A. Stedmon, Thomas Juul-Pedersen, Mikael K. Sejr, and Annette Bruhn. 2015. "The Influence of Glacial Melt Water on Bio-Optical Properties in Two Contrasting Greenlandic Fjords." *Estuarine, Coastal and Shelf Science* 163 (PB): 72–83. https://doi.org/10.1016/j.ecss.2015.05.041.

Nielsen, Claus. 2018. “Origin of the Trochophora Larva.” *Royal Society Open Science*. https://doi.org/10.1098/rsos.180042.

Nilsen, F., F. Cottier, R. Skogseth, and S. Mattsson. 2008. “Fjord-Shelf Exchanges Controlled by Ice and Brine Production: The Interannual Variation of Atlantic Water in Isfjorden, Svalbard.” *Continental Shelf Research* 28 (14): 1838–53. https://doi.org/10.1016/j.csr.2008.04.015.

O’Connor, Mary I., John F. Bruno, Steven D. Gaines, Benjamin S. Halpern, Sarah E. Lester, Brian P. Kinlan, and Jack M. Weiss. 2007. “Temperature Control of Larval Dispersal and the Implications for Marine Ecology, Evolution, and Conservation.” *Proceedings of the National Academy of Sciences of the United States of America*. https://doi.org/10.1073/pnas.0603422104.

Oksanen, J., F. Guillaume Blanchet, Michael Friendly, Roeland Kindt, Pierre Legendre, Dan McGlinn, Peter R. Minchin, et al. 2019. “Vegan: Community Ecology Package. R Package Version 2.5-2.” *Cran R*.

Oksanen, Jari, F Guillaume Blanchet, Roeland Kindt, P Legendre, Peter Minchin, R B O’Hara, Gavin Simpson, Peter Solymos, M H H Stevenes, and Helene Wagner. 2012. “Vegan: Community Ecology Package. R Package Version 2.0-2.”

Ortiz-Burgos, Selene. 2016. “Shannon-Weaver Diversity Index.” In *Encyclopedia of Estuaries*, edited by Michael J Kennish, 572–73. Dordrecht: Springer Netherlands. https://doi.org/10.1007/978-94-017-8801-4_233.

Overland, James, Edward Dunlea, Jason E. Box, Robert Corell, Martin Forsius, Vladimir Kattsov, Morten Skovgård Olsen, Janet Pawlak, Lars Otto Reiersen, and Muyin Wang. 2019. “The Urgency of Arctic Change.” *Polar Science*. https://doi.org/10.1016/j.polar.2018.11.008.

Parsons, Timothy R., Yoshiaki Maita, and Carol M. Lalli. 1984. “Determination of Chlorophylls and Total Carotenoids: Spectrophotometric Method.” In *A Manual of Chemical & Biological Methods for Seawater Analysis*. https://doi.org/10.1016/b978-0-08-030287-4.50032-3.

Pearre, Sifford. 2003. “Eat and Run? The Hunger/Satiation Hypothesis in Vertical Migration: History, Evidence and Consequences.” *Biological Reviews of the Cambridge Philosophical Society* 78 (1): 1–79. https://doi.org/10.1017/S146479310200595X.

Purcell, Jennifer E. 2005. “Climate Effects on Formation of Jellyfish and Ctenophore Blooms: A Review.” *Journal of the Marine Biological Association of the United Kingdom*. https://doi.org/10.1017/S0025315405011409.

Roman, M. R., D. V. Holliday, and L. P. Sanford. 2001. “Temporal and Spatial Patterns of Zooplankton in the Chesapeake Bay Turbidity Maximum.” *Marine Ecology Progress Series*. https://doi.org/10.3354/meps213215.

Scrosati, Ricardo A., Barbara van Genne, Christine S. Heaven, and Cortney A. Watt. 2011. “Species Richness and Diversity in Different Functional Groups across Environmental Stress Gradients: A Model for Marine Rocky Shores.” *Ecography*. https://doi.org/10.1111/j.1600-0587.2010.06119.x.

Shannon, C E. 1948. “A Mathematical Theory of Communication.” *Bell System Technical Journal* 27 (3): 379–423. https://doi.org/10.1002/j.1538-7305.1948.tb01338.x.

Shapiro, S. S., and M. B. Wilk. 1965. “An Analysis of Variance Test for Normality (Complete Samples).” *Biometrika*. https://doi.org/10.2307/2333709.

Sirenko. 2001. “List of Species of Free-Living Invertebrates of Eurasian Arctic Seas.” *Sciences-New York*.

Slagstad, D., I. H. Ellingsen, and P. Wassmann. 2011. “Evaluating Primary and Secondary Production in an Arctic Ocean Void of Summer Sea Ice: An Experimental Simulation Approach.” *Progress in Oceanography* 90 (1–4): 117–31. https://doi.org/10.1016/j.pocean.2011.02.009.

Solov’ev, K. A., and K. N. Kosobokova. 2003. “Feeding of the Chaetognaths Parasagitta Elegans Verrill (Chaetognatha) in the White Sea.” *Oceanology*.

Søreide, Janne E., Haakon Hop, Stig Falk-Petersen, Bjørn Gulliksen, and Edmond Hansen. 2003. “Macrozooplankton Communities and Environmental Variables in the Barents Sea Marginal Ice Zone in Late Winter and Spring.” *Marine Ecology Progress Series*. https://doi.org/10.3354/meps263043.

Søreide, Janne E., Eva V.A. Leu, JØRgen Berge, Martin Graeve, and Stig Falk-Petersen. 2010. “Timing of Blooms, Algal Food Quality and Calanus Glacialis Reproduction and Growth in a Changing Arctic.” *Global Change Biology*. https://doi.org/10.1111/j.1365-2486.2010.02175.x.

Spellerberg, Ian, and Peter Fedor. 2003. “A Tribute to Claude Shannon (1916–2001) and a Plea for More Rigorous Use of Species Richness, Species Diversity and the ‘Shannon–Wiener’ Index.” *Global Ecology & Biogeography* 12: 177–79. https://doi.org/10.1046/j.1466-822X.2003.00015.x.

Stübner, Eike. 2016. “Seasonality of Meroplankton in Svalbard Waters,” no. September: 1–57. https://munin.uit.no/bitstream/handle/10037/10018/thesis.pdf?sequence=6&isAllowed=y

.

Stübner, Eike, J. E. Søreide, M. Reigstad, M. Marquardt, and K. Blachowiak-Samolyk. 2016. "Year-Round Meroplankton Dynamics in High-Arctic Svalbard." *Journal of Plankton Research* 38 (3): 522–36. https://doi.org/10.1093/planktfbv124.

Svendsen, Harald, Agnieszka Beszczynska-Møller, Jon Ove Hagen, Bernard Lefauconnier, Vigdis Tverberg, Sebastian Gerland, Jon Børre Ørbøk, et al. 2002. "The Physical Environment of Kongsfjorden-Krossfjorden, and Arctic Fjord System in Svalbard." *Polar Research* 21 (1): 133–66. https://doi.org/10.1111/j.1751-8369.2002.tb00072.x.

Svensen, Camilla, Lena Seuthe, Yulia Vasilyeva, Anna Pasternak, and Edmond Hansen. 2011. "Zooplankton Distribution across Fram Strait in Autumn: Are Small Copepods and Protozooplankton Important?" *Progress in Oceanography*. https://doi.org/10.1016/j.pocean.2011.08.001.

Swalethorp, Rasmus, Evandro Malanski, Mette Dalgaardagersted, Torkel Gissel Nielsen, and Peter Munk. 2014. "Structuring of Zooplankton and Fish Larvae Assemblages in a Freshwaterinfluenced Greenlandic Fjord: Influence from Hydrography and Prey Availability." *Journal of Plankton Research* 37 (1): 102–19. https://doi.org/10.1093/plankt/fbu099.

Tang, Kam W., Torkel Gissel Nielsen, Peter Munk, John Mortensen, Eva Friis Møller, Kristine Engel Arendt, Kajsa Tönnesson, and Thomas Juul-Pedersen. 2011. "Metazooplankton Community Structure, Feeding Rate Estimates, and Hydrography in a Meltwater-Influenced Greenlandic Fjord." *Marine Ecology Progress Series* 434 (February 2014): 77–90. https://doi.org/10.3354/meps09188.

Tittensor, Derek P., Camilo Mora, Walter Jetz, Heike K. Lotze, Daniel Ricard, Edward Vanden Berghe, and Boris Worm. 2010. "Global Patterns and Predictors of Marine Biodiversity across Taxa." *Nature*. https://doi.org/10.1038/nature09329.

Toumi, Néji, Habib Ayadi, Olfa Abid, Jean François Carrias, Télesphore Sime-Ngando, Mekki Boukhris, and Abderrahmen Bouain. 2005. "Zooplankton Distribution in Four Ponds of Different Salinity: A Seasonal Study in the Solar Salterns of Sfax (Tunisia)." *Hydrobiologia*. https://doi.org/10.1007/s10750-004-9356-0.

Trudnowska, Emilia, Slawomir Sagan, Slawomir Kwasniewski, Miroslaw Darecki, and Katarzyna Blachowiak-Samolyk. 2015. "Fine-Scale Zooplankton Vertical Distribution in Relation to Hydrographic and Optical Characteristics of the Surface Waters on the Arctic Shelf." *Journal of Plankton Research* 37 (1): 120–33. https://doi.org/10.1093/plankt/fbu087.

Turner, J. T., H. Levinsen, T. G. Nielsen, and B. W. Hansen. 2001. “Zooplankton Feeding Ecology: Grazing on Phytoplankton and Predation on Protozoans by Copepod and Barnacle Nauplii in Disko Bay, West Greenland.” *Marine Ecology Progress Series*. https://doi.org/10.3354/meps221209.

Turner, Jefferson T. 2004. “The Importance of Small Planktonic Copepods and Their Roles in Pelagic Marine Food Webs.” In *Zoological Studies*.

Walkusz, Wojciech, Katharina Storemark, Torunn Skau, Charlotte Gannefors, and Marte Lundberg. 2003. “Zooplankton Community Structure; a Comparison of Fjords, Open Water and Ice Stations in the Svalbard Area.” *Polish Polar Research* 24 (2): 149–65.

Ward, P., and A. G. Hirst. 2007. “Oithona Similis in a High Latitude Ecosystem: Abundance, Distribution and Temperature Limitation of Fecundity Rates in a Sac Spawning Copepod.” *Marine Biology*. https://doi.org/10.1007/s00227-006-0548-1.

Wassmann, P., K. N. Kosobokova, D. Slagstad, K. F. Drinkwater, R. R. Hopcroft, S. E. Moore, I. Ellingsen, et al. 2015. “The Contiguous Domains of Arctic Ocean Advection: Trails of Life and Death.” *Progress in Oceanography* 139: 42–65. https://doi.org/10.1016/j.pocean.2015.06.011.

Węsławski, Jan Marcin, Friedrich Buchholz, Marta Głuchowska, and Agata Weydmann. 2017. “Ecosystem Maturation Follows the Warming of the Arctic Fjords.” *Oceanologia* 59 (4): 592–602. https://doi.org/10.1016/j.oceano.2017.02.002.

Weydmann, Agata, Janne E. Søreide, Sławek Kwaśniewski, Eva Leu, Stig Falk-Petersen, and Jørgen Berge. 2013. “Ice-Related Seasonality in Zooplankton Community Composition in a High Arctic Fjord.” *Journal of Plankton Research* 35 (4): 831–42. https://doi.org/10.1093/plankt/fbt031.

Wickham, Hadley. 2016a. “Getting Started with Ggplot2.” In . https://doi.org/10.1007/978-3-319-24277-4_2.

———. 2016b. “Tidyverse: Easily Install and Load ‘Tidyverse’ Packages.” *R Package Version 1.0.0*.

Wiedmann, Ingrid, Marit Reigstad, Miriam Marquardt, Anna Vader, and Tove M. Gabrielsen. 2016. “Seasonality of Vertical Flux and Sinking Particle Characteristics in an Ice-Free High Arctic Fjord-Different from Subarctic Fjords?” *Journal of Marine Systems* 154: 192–205. https://doi.org/10.1016/j.jmarsys.2015.10.003.

Witman, Jon D., Mathieu Cusson, Philippe Archambault, Andrew J. Pershing, and Nova Mieszkowska. 2008. “The Relation between Productivity and Species Diversity in Temperate-Arctic Marine Ecosystems.” In *Ecology*. https://doi.org/10.1890/07-1201.1.

Wyatt, T. 1973. “The Biology of Oikopleura Dioica and Fritillaria Borealis in the Southern Bight.” *Marine Biology*. https://doi.org/10.1007/BF00391778.

Zajaczkowski, Marek, and Maria Włodarska-Kowalczuk. 2007. “Dynamic Sedimentary Environments of an Arctic Glacier-Fed River Estuary (Adventfjorden, Svalbard). I. Flux, Deposition, and Sediment Dynamics.” *Estuarine, Coastal and Shelf Science* 74 (1–2): 285–96. https://doi.org/10.1016/j.ecss.2007.04.015.

Appendix

Appendix I: Station overview

Site	Date	Fjord	Research vessel	Latitude	Longitude	Local time
AF_1	14.05.2018	AF	Small boat	78.2330	15.6850	14:45
AF_2	14.05.2018	AF	Small boat	78.2450	15.6717	16:00
A_NC	14.05.2018	AF	Small boat	78.2662	15.6042	11:15
IsA	11.05.2018	AF	R/V Helmer Hanssen	78.2595	15.5217	
IsA	16.05.2018	AF	Small boat			
B_Ice	16.05.2018	BF	Small boat	78.5403	16.3500	11:10
B_Outer	10.05.2018	BF	R/V Helmer Hanssen			
B_Outer	16.05.2018	BF	Small boat	78.5117	16.2583	10:45
T_Ice	15.05.2018	TF	Small boat	78.3711	16.8627	14:00
T_RE_Degeer	15.05.2018	TF	Small boat	78.3462	16.3760	10:54
T_RE_Gips	15.05.2018	TF	Small boat	78.4277	16.5346	15:55
T_RE_Sassen	15.05.2018	TF	Small boat	78.3520	16.8131	12:19
T_Outer	11.05.2018	TF	R/V Helmer Hanssen			14:45
T_Outer	15.05.2018	TF	Small boat	78.3779	16.4742	
ME_3	11.05.2018	IF	R/V Helmer Hanssen	78.4195	15.8095	
IsK	10.05.2018	IF	R/V Helmer Hanssen			
IsK	16.05.2018	IF	Small boat	78.3071	15.1610	14:20
IsG	10.05.2018	IF	R/V Helmer Hanssen	78.1288	14.0028	
A_F1	18.06.2018	AF	Small boat	78.2333	15.6833	10:45
A_F2	18.06.2018	AF	Small boat	78.2450	15.6717	14:00
A_NC	18.06.2018	AF	Small boat	78.2650	15.6033	14:50
IsA	18.06.2018	AF	Small boat	78.2595	15.5217	18:00
B_RE	20.06.2018	BF	Small boat	78.7033	16.5717	11:25
B_Inner	20.06.2018	BF	Small boat	78.6483	16.9037	14:15
B_NC	20.06.2018	BF	Small boat	78.5900	16.6067	16:35
B_Outer	20.06.2018	BF	Small boat	78.5117	16.2583	18:00
T_Inner	22.06.2018	TF	Small boat	78.4353	17.3342	14:50
T_NC	22.06.2018	TF	Small boat	78.4239	17.0850	14:07
T_RE_Degeer	22.06.2018	TF	Small boat	78.3462	16.3760	11:00
T_RE_Gips	22.06.2018	TF	Small boat	78.4277	16.5346	17:10
T_RE_Sassen	22.06.2018	TF	Small boat	78.3520	16.8131	12:00
T_Outer	24.06.2018	TF	R/V Clione	78.3782	16.4731	11:45
ME_3	24.06.2018	IF	R/V Clione	78.4195	15.8095	16:45
IsK	24.06.2018	IF	R/V Clione	78.3457	15.5412	05:20
IsG	23.06.2018	IF	R/V Clione	78.1288	14.0028	23:25
A_F1	17.08.2018	AF	Small boat	78.2333	15.6833	14:10
A_F2	17.08.2018	AF	Small boat	78.2450	15.6717	13:46
A_NC	17.08.2018	AF	Small boat	78.2650	15.6033	10:26
IsA	18.08.2018	AF	R/V Helmer Hanssen	78.2595	15.5217	05:45
B_RE	24.08.2018	BF	Small boat	78.7033	16.5717	11:11
B_Inner	24.08.2018	BF	Small boat	78.6483	16.9037	12:31
B_NC	24.08.2018	BF	Small boat	78.5900	16.6067	15:05
B_Outer	08.08.2018	BF	R/V Helmer Hanssen	78.5117	16.2583	15:03
T_Inner	20.08.2018	TF	Small boat	78.4353	17.3342	15:13
T_NC	22.08.2018	TF	Small boat	78.4239	17.0850	10:41
T_RE_Degeer	22.08.2018	TF	Small boat	78.3462	16.3760	10:37
T_RE_Gips	22.08.2018	TF	Small boat	78.4277	16.5346	12:26
T_RE_Sassen	20.08.2018	TF	Small boat	78.3520	16.8131	14:32
T_Outer	22.08.2018	TF	Small boat	78.3782	16.4731	13:31
ME_3	24.08.2008	IF	Small boat	78.4195	15.8095	16:00
IsK	18.08.2008	IF	R/V Helmer Hanssen	78.3071	15.1610	01:33
IsG	17.08.2019	IF	R/V Helmer Hanssen	78.1288	14.0028	17:50

Appendix II: Terrestrial influence

Figure I: Satellite picture of Isfjorden, showing the terrestrial input from air

Figure II: Input from river, picture from Isfjorden in July 2018

Appendix III: Ice conditions and weather

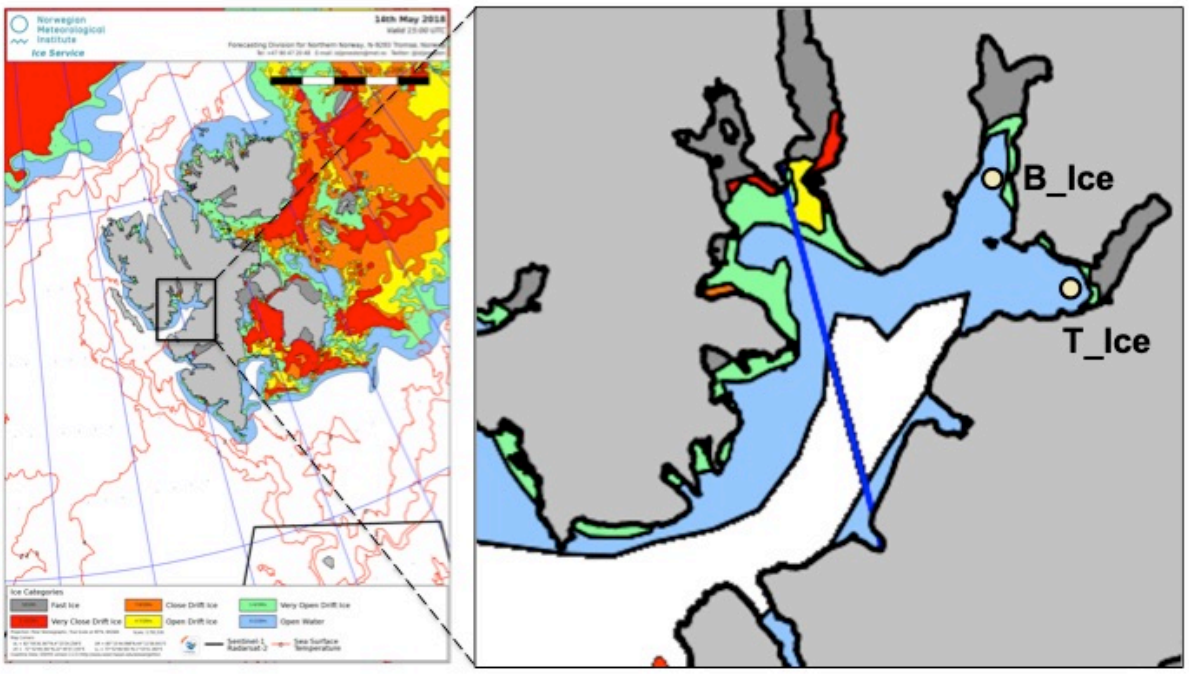

Figure III: Sea ice extent from 14th of August 2018 around Svalbard. The colors represent fast ice (grey), very close drift ice (red), close drift ice (orange), open drift ice (yellow), very open drift ice (green) and open water (blue). The two white dots represent the two inner stations (B_Ice and T_Ice) which replaced the innermost stations in Billefjorden and Tempelfjorden. The overview is retrieved from *met.no*.

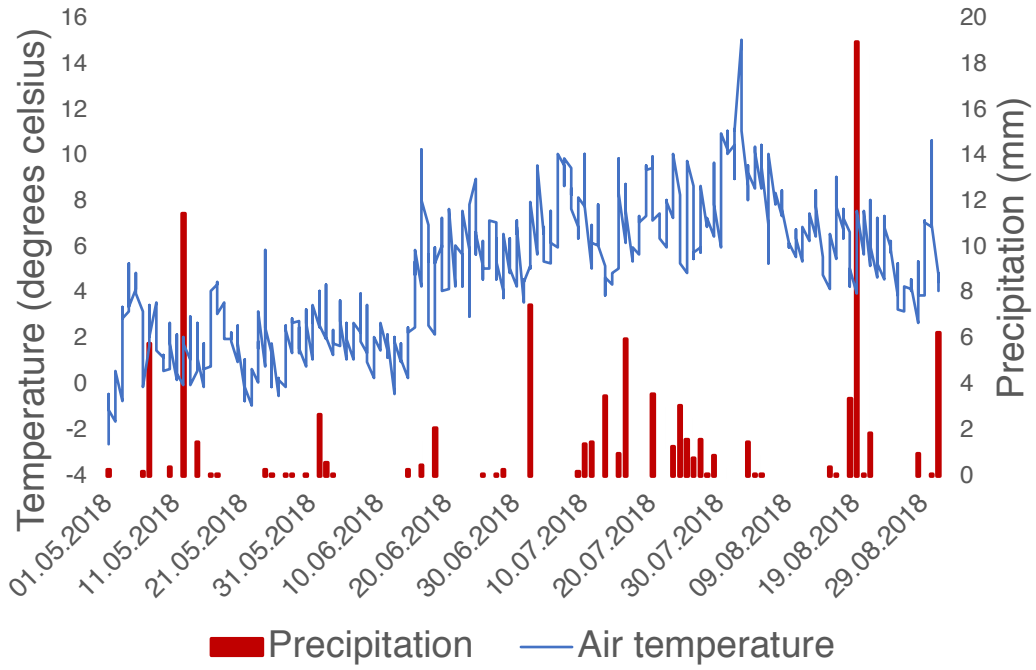

Figure IV: Weather from Svalbard Lufthavn from 1st of May to 29th of August 2018

Appendix IV: Physical parameters (15m)

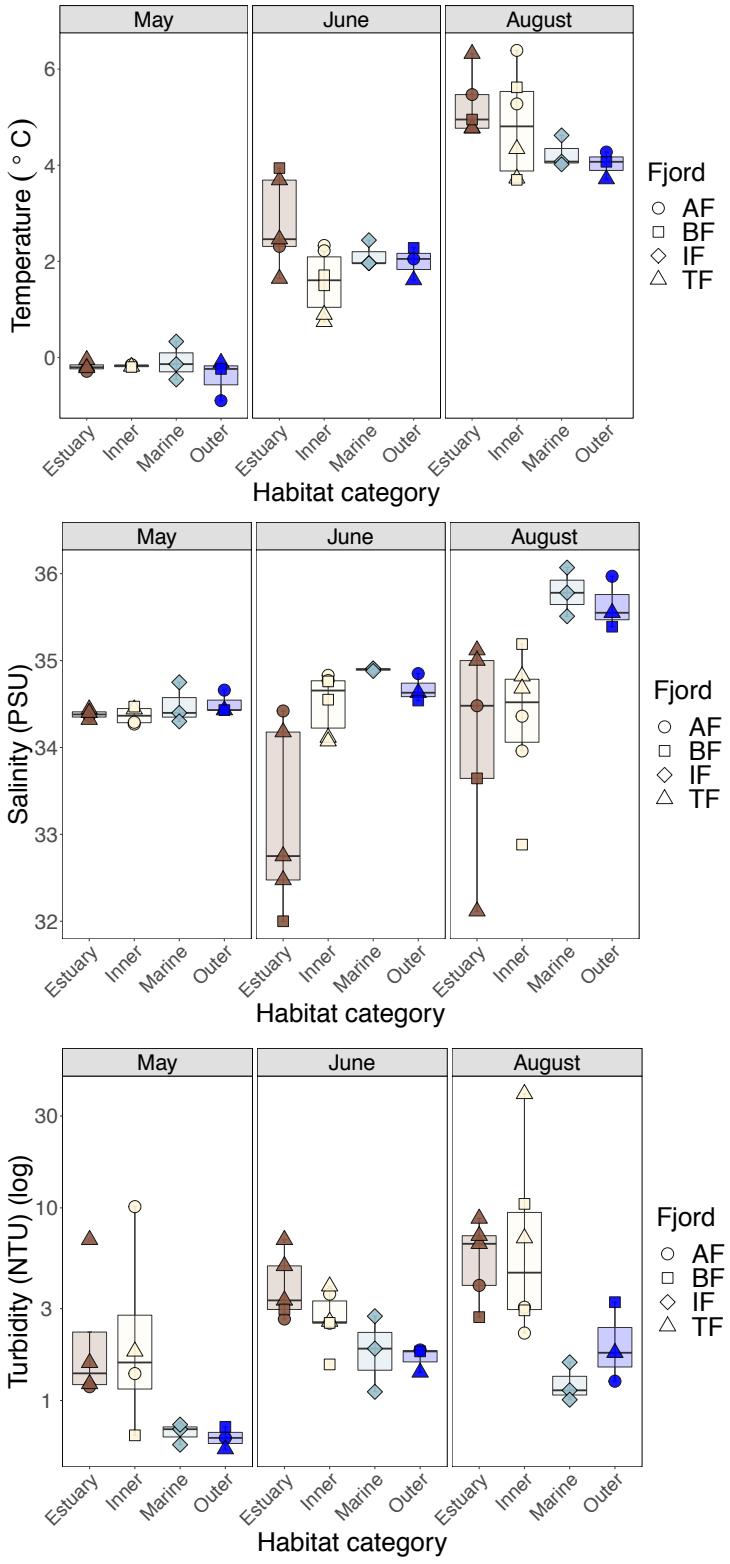

Figure V: Temperature (°C), salinity (PSU) and turbidity (NTU) measured at 15m depth in May, June, and August. The sites are classified as habitat categories: River estuaries ("Estuary", brown), inner ("Inner", yellow), outer ("Outer", turquoise") or marine endpoints ("Marine", blue), and each fjord is represented as a shape (Adventfjorden (AF)=circle, Billefjorden (BF)=square, Isfjorden (IF)=diamond, Tempelfjorden (TF)= triangle).

Appendix V: Chlorophyll *a* (15m)

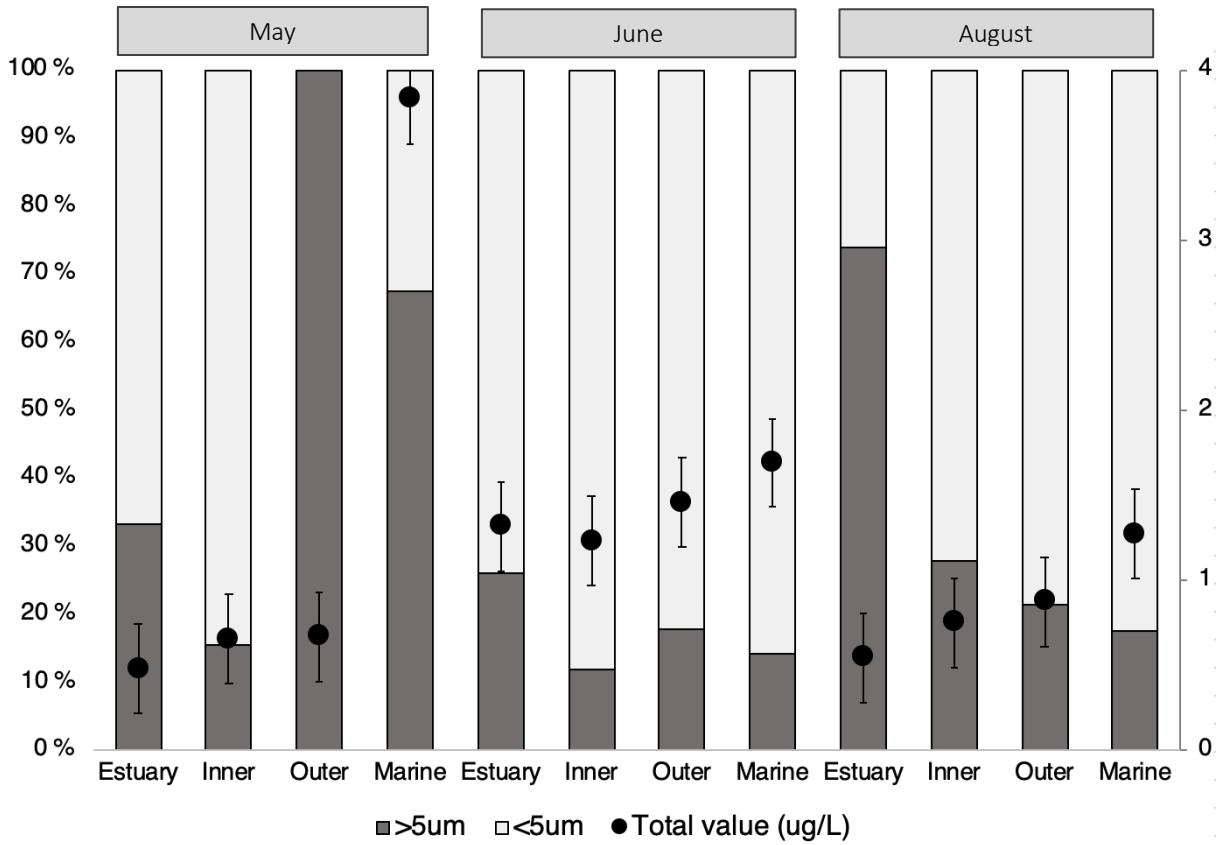

Figure VI: Chlorophyll *a*: Relative and total concentration of chlorophyll *a* (µg/L) measured at 15m in May, June, and August. The first y-axis displays the relative abundance of the two size fractions, cells larger than 5µm (white) and cells smaller than 5µm (grey). The second y-axis displays the total concentration of chlorophyll *a*, measured as µg/L. The sites are classified as habitat categories: River estuaries ("Estuary"), inner ("Inner"), outer ("Outer",) or marine endpoints ("Marine").

Appendix VI: Zooplankton (m^{-2})

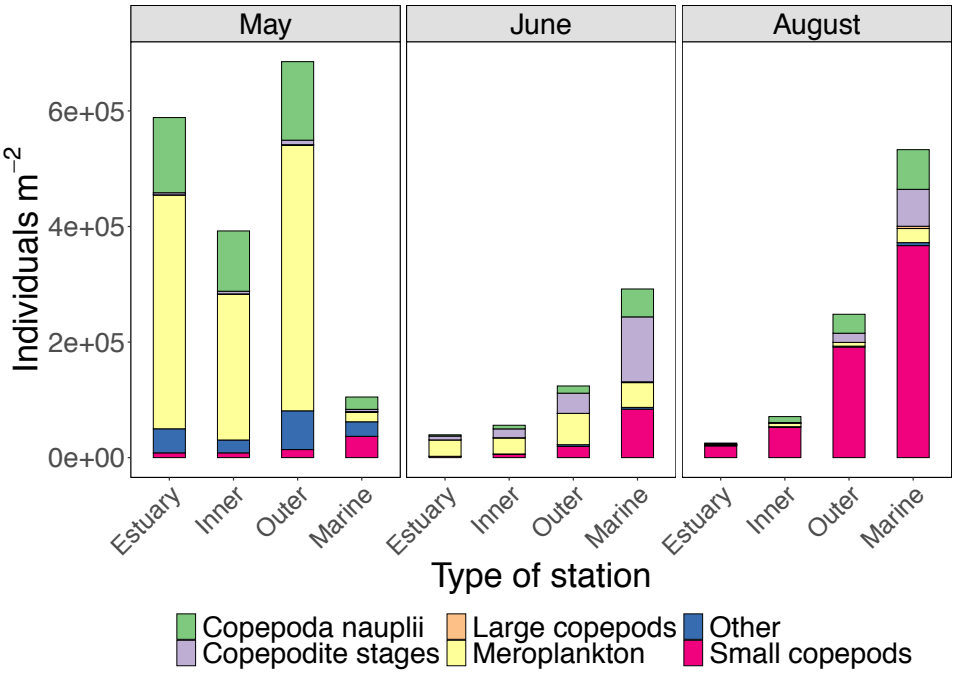

Figure VII: Abundance (individuals m^{-2}): The total (individuals m^{-2}) of zooplankton shown from May to June, classified as river estuaries ("Estuary"), inner ("Inner"), outer ("Outer") or marine endpoints ("Marine"). The different groups of zooplankton are marked as green (copepod nauplii), purple (copepodite stages), orange (large copepods), yellow (meroplankton), blue (other) and pink (small copepods). Shown are mean values for all fjords studied.

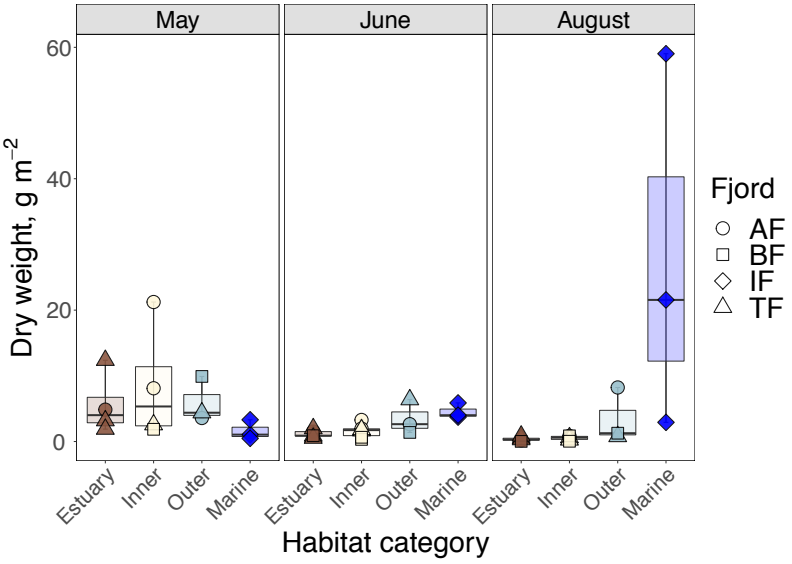

Figure VIII: Biomass (dry weight, g m^{-2}). The biomass (dry weight, g m^{-2}) measured in May, June and August. The sites are classified as habitat categories: River estuaries ("Estuary", brown), inner ("Inner", yellow), outer ("Outer", turquoise") or marine endpoints ("Marine", blue), and each fjord is represented as a shape (Adventfjorden (AF)=circle, Billefjorden (BF)=square, Isfjorden (IF)= diamond, Tempelfjorden (TF)=triangle)

Appendix VII: Metadata - Environmental and physical parameters

Table I: Environmental and physical data from May 2018

Site	Temperature (surface)	Temperature (15m)	Salinity (surface)	Salinity (15m)	pH (surface)	pH (15m)	Chl-a 5um (surface)	Chl-a 5um (15m)	Chl-a GFF (surface)	Chl-a GFF (15m)	Turbidity (surface)	Turbidity (15m)	Julian day	Secchi depth	Species richness	Shannon Wiener Diversity Index
AF_1	0.143	-0.287	33.46	34.36	8.88	8.3	0.23	0.0691	0.24	0.4426	2.16	1.18	134	6.5	12	0.7634788
AF_2	0.861	-0.155	33.23	34.27	8.38	8.35	0.0334	0.0731	0.1388	1.02	6.58	10.15	134	5.2	13	0.7607931
A_NC	0.53	-0.15	33.85	34.29	8.1	8.29	0.0703	0.072	0.395	0.6403	4.32	1.38	134	3.2	12	0.893541
IsA	-0.848	-0.902	34.6	34.66	8.08	8.26	0.2165	0.1745	0.4346	0.5553	0.56	0.64	136	10	13	1.1972255
B_Ice	-0.23	-0.189	33.74	34.44	8.34	8.34	0.0759	0.1162	0.3984	0.5344	1.41	1.8	135	11	13	1.3886992
B_Outer	0.171	-0.191	32.82	34.44	8.29	8.28	0.0544	0.1609	0.1836	0.601	4.82	6.83	135	7.5	13	1.2271714
T_Ice	0.655	-0.049	33.67	34.32	8.26	8.32	0.0425	0.0708	0.2	0.5893	1.06	1.57	135	9	15	0.7197229
T_RE_Degeer	-0.21	-0.217	34.13	34.4	8.23	8.06	0.1428	0.3326	0.3111	0.2833	7.06	1.22	135	8	13	0.8071439
T_RE_Gips	-0.09	-0.11	34.42	34.43	8.11	8.11	0.2403	0.4647	0.7027	0.85	0.6	0.56	135	9	13	1.1092289
T_RE_Sassen	-0.093	-0.195	32.88	34.47	8.12	8.14	0.0635	0.1428	0.1683	0.4154	1.15	0.66	136	13	10	1.5359931
T_Outer	0.379	-0.244	34.27	34.43	8.12	8.14	2.0343	2.091	2.431	0.595	0.61	0.73	136	9	13	1.0349536
ME_3	-0.06	-0.14	34.353	34.398	8.1	8.18	1.683	3.5303	2.754	4.947	0.6	0.59	136	8	14	2.0497125
IsK	0.645	0.329	34.6	34.75	8	8.25	4.7203	3.3547	5.508	5.372	0.85	0.71	136	7	15	1.8894094
IsG	-0.4	-0.46	34.301	34.3	8.07	8.17	1.122	0.85	0.656	1.1617	0.84	0.75	136	9	14	2.0977659

Table II: Environmental and physical data from June 2018

Site	Temperature (surface)	Temperature (15m)	Salinity (surface)	Salinity (15m)	pH (surface)	pH (15m)	Chl-a 5um (surface)	Chl-a 5um (15m)	Chl-a GFF (surface)	Chl-a GFF (15m)	Turbidity (surface)	Turbidity (15m)	Julian day	Secchi depth	Species richness	Shannon Wiener Diversity Index
A_F1	3.11	2.31	9.64	34.42	7.89	8.13	0.2669	0.238	0.3989	1.3617	46.33	2.65	169	0.4	10	1.2616735
A_F2	2.86	2.33	34.44	34.83	8.14	8.14	0.5559	0.2465	0.6222	1.4977	40.4	2.52	169	0.3	13	1.1634443
A_NC	2.75	2.22	31.79	34.77	8.17	8.2	0.3978	0.2006	1.853	1.3804	14.69	3.57	169	0.8	13	1.4608337
IsA	2.29	2.05	34.63	34.85	8.19	8.05	0.3247	0.5304	2.992	0.4284	4.33	1.83	169	2.5	17	1.7976415
B_RE	5.485	0.737	28.813	34.114	8.21	8.23	0.1762	0.0799	0.697	0.4828	5.75	3.92	173	1	14	0.8183347
B_Inner	3.922	0.891	29.603	34.072	8.22	8.19	0.1128	0.1082	0.714	0.816	8.49	2.57	173	1	14	1.0001672
B_NC	4.961	2.459	31.989	32.475	8.21	8.21	0.1258	0.1258	0.782	0.782	13.3	5	173	0.3	9	0.3279053
B_Outer	4.412	1.641	31.884	34.177	8.26	8.24	0.2346	0.2346	1.4903	0.148	10.83	3.31	173	1	10	0.4899445
T_Inner	4.115	3.686	33.183	32.75	7.91	8.19	0.5859	0.9588	2.193	3.2413	8.78	6.83	173	0.8	13	0.843499
T_NC	2.91	1.61	33.92	34.63	8	8.21	0.4278	0.1332	1.547	1.3147	7.65	1.4	175	3.5	14	1.2882897
T_RE_Degeer	4.96	3.94	26.47	32	8	8.2	0.3649	0.1558	0.7083	1.717	5.59	2.97	171	1	12	0.5652646
T_RE_Gips	2.57	1.71	32.58	34.55	8.31	8.25	0.1417	0.0992	0.4981	1.2523	8.05	2.53	171	1.4	8	0.426248
T_RE_Sassen	3.46	1.5	34.01	34.76	8.26	8.25	0.0941	0.1309	0.816	1.9493	1.4	1.54	171	6	9	0.6030244
T_Outer	3.89	2.28	34.05	34.54	8.23	8.26	0.1094	0.1139	0.153	2.6237	2.98	1.8	171	5	11	0.9564754
ME_3	4.71	1.96	34.25	34.9	8.22	8.23	0.2238	0.2306	1.581	1.5855	2.06	2.74	175	5.5	11	1.5555263
IsK	4.71	1.96	34.25	34.91	8.24	8.2	0.2125	0.0754	2.1533	0.5752	2.88	1.11	175	5.5	12	1.5105196
IsG	3.36	2.44	34.62	34.88	7.95	8.12	0.7367	0.4108	0.443	2.9127	3.34	1.86	175	8	13	1.8072071

Table III: Environmental and physical data from August 2018

Site	Temperature (surface)	Temperature (15m)	Salinity (surface)	Salinity (15m)	pH (surface)	pH (15m)	Chl-a 5um (surface)	Chl-a 5um (15m)	Chl-a GFF (surface)	Chl-a GFF (15m)	Turbidity (surface)	Turbidity (15m)	Julian day	Secchi depth	Species richness	Shannon Wiener Diversity Index
A_F1	7.134	5.47	33.59	34.48	7.82	7.98	0.5287	0.3253	1.3634	0.629	4.633	3.96	229	2.4	9	0.8842198
A_F2	7.703	5.276	30.37	34.36	7.94	8.04	0.8387	0.4692	1.972	1.4507	7.237	3.05	229	1.9	14	1.3528737
A_NC	8.939	6.389	26.75	33.96	8.06	8.03	0.5365	0.2142	1.4416	1.2863	5.763	2.24	229	1.6	10	1.0691482
IsA	6.3346	4.2739	34.65	35.97	7.89	8.03	0.3944	0.1255	1.1978	0.5168	1.64	1.26	230	4	14	0.9354559
B_RE	6.51	3.726	25.9	34.82	8.16	8.04	1.6207	0.2185	2.7993	0.2414	7.913	39.07	232	1.2	11	1.1085513
B_Inner	4.994	4.34	17.79	34.68	8.09	7.98	0.1904	0.238	0.3219	0.442	5.453	6.97	234	2.5	11	0.9976565
B_NC	6.32	4.769	2.42	35.12	8.49	7.97	0.1326	0.408	0.055	0.5876	297.333	8.81	234	0.12	8	0.6169346
B_Outer	6.32	6.32	27.68	32.115	8.13	8.13	0.2947	0.2947	0.085	0.085	6.51	6.51	234	2.8	12	0.9612535
T_Inner	7.822	4.769	19.64	35	7.81	8.02	0.317	0.7197	0.601	0.952	298.333	7.17	234	0.12	9	0.6788748
T_NC	6.938	3.711	28.62	35.55	8.05	8.01	0.4834	0.2941	0.765	1.088	2.817	1.77	234	3.2	13	0.9050111
T_RE_Degeer	4.951	4.951	33.39	33.644	7.93	8.05	0.2601	0.2601	1.8303	1.8303	2.013	2.71	236	4.3	7	0.9589546
T_RE_Gips	4.432	3.695	20.37	35.19	8.37	8.08	0.403	0.0788	0.714	1.06	42.533	10.49	236	0.4	13	1.0069564
T_RE_Sassen	5.621	5.621	32.496	32.882	8.03	8.11	0.0369	0.0369	0.8727	0.8727	1.457	2.94	236	5.1	1	-
T_Outer	6.854	4.071	32.09	35.39	8.04	8	0.0873	0.1383	0.731	1.0143	2.863	3.24	234	3.2	14	0.8837824
ME_3	6.733	4.075	32.01	35.51	8.1	8.1	0.0104	0.1054	0.6177	1.445	1.093	1.13	236	7.2	15	0.9690066
IsK	6.0816	4.0178	34.85	36.07	8.08	8.07	0.1303	0.069	0.7106	1.0697	0.807	1.01	230	7	13	1.617135
IsG	7.0603	4.6214	33.46	35.78	8.07	8.05	0.1547	0.489	1.7267	1.292	1.097	1.58	229	6	15	1.4925091

Appendix VIII: Zooplankton raw data (ind. m^{-3})

Table IV: Zooplankton (ind. m^{-3}) from May 2018

Taxon	AF_1	AF_2	A_NC	IsA	B_Ice	B_Outer	T_Ice	T_RE_Degeer	T_RE_Gips	T_RE_Sassen	T_Outer	ME_3	IsK	IsG
Copepoda (nauplii)	0.00	0.00	0.00	0.00	16.00	166.40	10.67	0.00	0.00	6.86	765.71	0.00	0.00	0.00
Calanoida (nauplii)	4546.67	1666.67	6320.00	1172.21	584.00	6048.00	5728.00	3330.00	4650.00	532.57	811.43	192.06	136.75	1.58
Oithona similis	13.33	53.33	48.00	60.63	0.00	160.00	14.93	460.00	160.00	86.86	137.14	62.18	198.29	1.41
Oithona atlantica	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.37	0.00
Pseudocalanus spp.	173.33	113.33	304.00	40.42	39.00	115.20	70.40	70.00	200.00	32.00	114.29	51.12	54.70	2.57
Microcalanus spp.	0.00	0.00	0.00	3.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	49.74	146.32	0.17
Microsetella norvegica	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Triconia borealis	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.37	0.00
Oncaea spp. (juvenile)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Calanus spp. (CI)	106.67	40.00	48.00	64.00	14.00	64.00	85.33	170.00	210.00	41.14	45.71	19.34	1.37	0.17
Calanus spp. (CII)	0.00	13.33	0.00	6.74	1.00	6.40	2.13	30.00	10.00	6.86	34.29	8.29	4.10	0.25
Calanus spp. (CIII)	0.00	0.00	0.00	0.00	1.00	0.00	2.13	0.00	0.00	4.57	0.00	0.00	4.10	0.17
Calanus spp. (CIV)	13.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	82.29	11.43	0.00	6.84	1.08
Calanus spp. (CV)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	50.29	22.86	4.15	9.57	0.58
Calanus spp. (adult female)	0.00	0.00	0.00	0.00	0.00	6.40	0.00	0.00	0.00	6.86	45.71	5.53	6.84	0.41
Metridia longa	0.00	0.00	0.00	0.00	0.00	0.00	2.13	0.00	0.00	0.00	0.00	2.76	5.47	0.17
Cirripedia (nauplii)	18893.33	7633.33	15408.00	3152.84	507.00	7596.80	755.20	26240.00	12590.00	409.14	7988.57	150.60	58.80	5.47
Cirripedia (cypris)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.38	0.00	0.00
Echinodermata (larvae)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.00	0.00	0.00	9.67	24.62	0.00
Bivalvia (veliger)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.37	0.00
Polychaeta (juvenile)	13.33	40.00	96.00	47.16	35.00	153.60	36.27	320.00	200.00	2.29	45.71	0.00	0.00	0.33
Hyas araneus (larvae)	0.00	0.00	16.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Alentia gelatinosa (trochophore)	0.00	6.67	0.00	16.84	0.00	70.40	89.60	50.00	70.00	0.00	0.00	0.00	0.00	0.00
Trochophore (unidentified)	93.33	0.00	80.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08
Zoea (larvae)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Taxon	AF_1	AF_2	A_NC	IsA	B_Ice	B_Outer	T_Ice	T_RE_Degeer	T_RE_Gips	T_RE_Sassen	T_Outer	ME_3	IsK	IsG
Dimophyes arctica	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Beröe cucumis	0.00	6.67	0.00	0.00	0.00	0.00	2.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aglantha digitale	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mertensia ovum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Limacina helicina (veliger)	0.00	0.00	0.00	0.00	0.00	6.40	0.00	0.00	0.00	0.00	11.43	0.00	0.00	0.00
Euphausiidae (furcilia)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Euphausiidae (calyptopis)	13.33	26.67	32.00	33.68	11.00	38.40	10.67	170.00	10.00	0.00	777.14	2.76	0.00	0.17
Euphausiidae (metanauplii)	306.6	226.67	528.00	151.58	38.00	377.60	25.60	1600.00	300.00	0.00	0.00	60.79	6.84	1.08
Euphausiidae (nauplii)	93.33	66.67	64.00	202.11	0.00	0.00	0.00	500.00	700.00	201.14	34.29	178.24	5.47	2.16
Oikopleura spp.	0.00	0.00	0.00	0.00	0.00	0.00	2.13	0.00	0.00	0.00	22.86	0.00	0.00	0.00
Fritillaria borealis	240.0	13.33	192.00	107.79	127.00	1190.40	260.27	120.00	710.00	50.29	22.86	11.05	2.74	2.40
Parasagitta elegans	0.00	0.00	0.00	0.00	1.00	0.00	2.13	10.00	0.00	0.00	0.00	0.00	0.00	0.00
Chaetognatha (unidentified)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isopoda (larvae)	0.00	6.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Thysanoessa inermis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Themisto abyssorum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table V: Zooplankton (ind. m^{-3}) from June 2018

Taxon	A_F1	A_F2	A_NC	IsA	B_RE	B_Inner	B_NC	B_Outer	T_Inner	T_NC	T_RE_Degeer	T_RE_Gips	T_RE_Sassen	T_Outer	ME_3	IsK	IsG
Copepoda (nauplii)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Calanoida (nauplii)	440.00	544.0	274.29	198.74	74.07	194.12	65.00	250.00	8.00	328.00	56.67	6.32	9.85	30.48	392.31	100.00	264.62
Oithona similis	133.33	200.0	177.14	89.26	18.52	111.76	35.00	230.00	8.00	416.00	90.00	4.91	0.00	20.32	327.69	95.20	178.46
Oithona atlantica	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.26
Pseudocalanus spp.	26.67	32.00	45.71	37.05	107.41	452.94	25.00	440.00	17.60	400.00	66.67	7.02	9.85	27.94	360.00	41.60	192.82
Microcalanus spp.	0.00	0.00	0.00	3.37	7.41	29.41	0.00	0.00	0.00	32.00	0.00	0.00	0.00	0.00	64.62	4.80	71.79
Microsetella norvegica	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Triconia borealis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oncaea spp. (juvenile)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.40	0.00
Calanus spp. (CI)	40.00	68.00	48.57	25.26	11.11	223.53	0.00	90.00	0.00	56.00	6.67	0.70	0.00	10.16	143.08	20.00	38.97
Calanus spp. (CII)	115.56	144.00	151.43	67.37	77.78	552.94	35.00	440.00	9.60	336.00	6.67	7.72	2.46	25.40	281.54	72.80	155.90
Calanus spp. (CIII)	368.89	248.0	268.57	65.68	100.00	652.94	295.00	710.00	8.00	632.00	96.67	19.65	25.85	62.22	355.38	72.00	151.79
Calanus spp. (CIV)	120.00	204.0	134.29	43.79	66.67	264.71	285.00	690.00	22.40	392.00	60.00	19.65	24.62	35.56	276.92	62.40	112.82
Calanus spp. (CV)	22.22	36.00	20.00	6.74	25.93	0.00	15.00	30.00	6.40	80.00	40.00	8.42	35.69	12.70	55.38	22.40	41.03
Calanus spp. (adult female	0.00	0.00	0.00	0.00	3.70	0.00	0.00	0.00	3.20	0.00	0.00	1.40	1.23	0.00	4.62	4.00	10.26
Metridia longa	0.00	0.00	0.00	1.68	37.04	0.00	0.00	0.00	1.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cirripedia (nauplii)	173.33	316.00	225.71	30.32	770.37	1235.3	1195.0	6850.00	70.40	904.00	466.67	66.67	75.08	118.10	133.85	1.60	28.72
Cirripedia (cypris)	231.11	752.0	200.00	42.11	474.07	1317.6	1685.0	4530.0	211.20	1584.0	1770.0	247.02	285.54	140.95	452.31	30.40	80.00
Echinodermata (larvae)	8.89	8.00	2.86	0.00	0.00	0.00	0.00	0.00	0.00	8.00	0.00	0.00	0.00	0.00	0.00	0.80	4.10

Taxon	A_F1	A_F2	A_NC	IsA	B_RE	B_Inner	B_NC	B_Outer	T_Inner	T_NC	T_RE_Degeer	T_RE_Gips	T_RE_Sassen	T_Outer	ME_3	IsK	IsG
Bivalvia (veliger)	17.7	0.00	0.00	18.53	11.11	29.41	10.00	180.00	17.60	128.00	13.33	2.81	8.62	6.35	9.23	0.00	47.18
Polychaeta (juvenile)	4.44	8.00	25.71	5.05	18.52	35.29	0.00	130.00	1.60	56.00	26.67	0.00	0.00	0.00	0.00	0.00	4.10
Hyas araneus (larvae)	0.00	8.00	2.86	0.00	0.00	0.00	5.00	0.00	0.00	16.00	0.00	0.00	0.00	0.00	0.00	0.80	0.00
Alentia gelatinosa (trochophore)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Trochophore (unidentified)	0.00	0.00	2.86	3.37	3.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.80	0.00
Zoea (larvae)	0.00	0.00	2.86	3.37	3.70	0.00	0.00	0.00	0.00	24.00	0.00	0.00	1.23	1.27	4.62	0.00	0.00
Dimophyes arctica	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Beröe cucumis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aglantha digitale	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mertensia ovum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Limacina helicina (veliger)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.33	0.00	0.00	0.00	0.00	0.00	0.00
Euphausiidae (furcilia)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.62	0.00	0.00
Euphausiidae (calyptopis)	0.00	4.00	0.00	3.37	0.00	29.41	0.00	30.00	0.00	24.00	3.33	0.00	0.00	1.27	0.00	0.00	4.10
Euphausiidae (metanauplii)	0.00	4.00	0.00	0.00	0.00	11.76	0.00	0.00	1.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Euphausiidae (nauplii)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oikopleura spp.	0.00	0.00	0.00	3.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fritillaria borealis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Parasagitta elegans	0.00	0.00	5.71	3.37	3.70	11.76	0.00	10.00	0.00	0.00	6.67	0.00	0.00	1.27	13.85	0.00	0.00
Chaetognatha (unidentified)	0.00	4.00	0.00	3.37	0.00	11.76	0.00	0.00	1.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isopoda (larvae)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Thysanoessa inermis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Themisto abyssorum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table VI: Zooplankton (ind. m^{-3}) from August 2018

Taxon	A_F1	A_F2	A_NC	IsA	B_RE	B_Inner	B_NC	B_Outer	T_Inner	T_NC	T_RE_Degeer	T_RE_Gips	T_Outer	ME_3	IsK	IsG
Copepoda (nauplii)	44.80	270.00	1184.3	493.33	22.00	51.43	53.33	320.00	56.00	177.50	0.00	10.00	43.64	15.00	47.58	219.85
Calanoida (nauplii)	198.40	173.33	690.20	440.00	48.00	91.43	32.00	80.00	336.00	260.00	32.00	8.50	69.82	42.00	105.08	366.41
Oithona similis	2476.80	1940.00	6988.2	4606.6	570.00	1371.43	1829.33	2920.00	4112.00	2437.50	288.00	277.50	1227.64	550.50	450.06	1900.76
Oithona atlantica	0.00	13.33	0.00	206.67	0.00	0.00	0.00	0.00	0.00	5.00	0.00	0.50	7.27	8.25	93.18	105.34
Pseudocalanus spp.	128.00	200.00	407.84	66.67	112.00	331.43	53.33	80.00	312.00	167.50	32.00	82.50	144.00	96.75	519.45	435.11
Microcalanus spp.	0.00	26.67	0.00	13.33	0.00	0.00	0.00	0.00	0.00	15.00	0.00	5.50	4.36	3.75	39.65	73.28
Microsetella norvegica	25.60	0.00	7.84	6.67	20.00	11.43	0.00	66.67	40.00	10.00	0.00	0.00	2.91	1.50	0.00	0.00
Triconia borealis	0.00	3.33	0.00	6.67	0.00	2.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	31.72	18.32
Oncaea spp. (juvenile)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Calanus spp. (CI)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Calanus spp. (CII)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.58
Calanus spp. (CIII)	0.00	10.00	7.84	40.00	0.00	0.00	10.67	0.00	16.00	15.00	0.00	0.00	0.00	0.00	0.00	36.64
Calanus spp. (CIV)	6.40	30.00	15.69	26.67	2.00	0.00	37.33	40.00	8.00	15.00	0.00	0.50	4.36	3.00	41.64	77.86
Calanus spp. (CV)	0.00	100.00	23.53	433.33	32.00	5.71	149.33	306.67	224.00	52.50	0.00	21.50	74.18	44.25	216.11	311.45
Calanus spp. (adult female	0.00	0.00	0.00	0.00	0.00	0.00	5.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.16
Metridia longa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	21.81	13.74
Cirripedia (nauplii)	0.00	13.33	15.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cirripedia (cypris)	12.80	0.00	0.00	0.00	0.00	0.00	0.00	26.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Echinodermata (larvae)	0.00	6.67	7.84	13.33	2.00	5.71	0.00	26.67	24.00	2.50	0.00	0.50	0.00	0.75	0.00	0.00
Bivalvia (veliger)	307.20	330.00	847.06	133.33	58.00	77.14	160.00	266.67	56.00	85.00	0.00	7.00	77.09	21.75	45.60	215.27
Polychaeta (juvenile)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	26.67	0.00	0.00	40.00	0.00	1.45	0.00	0.00	0.00
Hyas araneus (larvae)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.37
Alentia gelatinosa (trochophore)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Trochophore (unidentified)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Zoea (larvae)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Taxon	A_F1	A_F2	A_NC	IsA	B_RE	B_Inner	B_NC	B_Outer	T_Inner	T_NC	T_RE_Degeer	T_RE_Gips	T_Outer	ME_3	IsK	IsG
Dimophyes arctica	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Berõe cucumis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aglantha digitale	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mertensia ovum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.60	0.50	0.11	0.01	0.00	0.00
Limacina helicina (veliger)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Euphausiidae (furcilia)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Euphausiidae (calyptopis)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Euphausiidae (metanauplii)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Euphausiidae (nauplii)	0.00	0.00	0.00	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.37
Oikopleura spp.	0.00	6.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fritillaria borealis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Parasagitta elegans	0.00	10.00	0.00	6.80	4.00	2.29	10.67	3.20	1.60	7.50	0.00	0.64	3.78	2.64	2.50	5.37
Chaetognatha (unidentified)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isopoda (larvae)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Thysanoessa inermis	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00	5.00	0.00	0.64	0.87	0.08	0.12	0.00
Themisto abyssorum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.61

Appendix IX: Zooplankton biomass

Site	Date	Biomass (g d.w. m^{-2})	Biomass (g d.w.m^{-3})
AF_1	14.05.2018	4.8512	0.2426
AF_2	14.05.2018	8.1072	0.2027
A_NC	14.05.2018	21.2320	0.5308
IsA	11.05.2018	3.5776	0.0377
B_Ice	16.05.2018	1.8592	0.0266
B_Outer	10.05.2018	9.9072	0.1415
T_Ice	15.05.2018	2.5632	0.0256
T_RE_Degeer	15.05.2018	12.3680	0.3092
T_RE_Gips	15.05.2018	1.8880	0.0629
T_RE_Sassen	15.05.2018	3.1776	0.1589
T_Outer	11.05.2018	4.3840	0.1096
ME_3	11.05.2018	1.0496	0.0054
IsK	10.05.2018	3.3088	0.0170
IsG	10.05.2018	0.4816	0.0025
A_F1	18.06.2018	1.5088	0.0838
A_F2	18.06.2018	3.2816	0.0820
A_NC	18.06.2018	1.9632	0.0561
IsA	18.06.2018	2.6400	0.0278
B_RE	20.06.2018	0.8896	0.0890
B_Inner	20.06.2018	0.3248	0.0085
B_NC	20.06.2018	0.6464	0.0497
B_Outer	20.06.2018	1.3824	0.0197
T_Inner	22.06.2018	1.6448	0.0457
T_NC	22.06.2018	1.8304	0.1077
T_RE_Degeer	22.06.2018	0.5184	0.0518
T_RE_Gips	22.06.2018	1.9728	0.2466
T_RE_Sassen	22.06.2018	0.8368	0.1674
T_Outer	24.06.2018	6.3744	0.1275
ME_3	24.06.2018	5.8752	0.0452
IsK	24.06.2018	3.7152	0.0149
IsG	23.06.2018	4.0032	0.0154
A_F1	17.08.2018	0.2016	0.0183
A_F2	17.08.2018	0.8448	0.0282
A_NC	17.08.2018	0.5856	0.0344
IsA	18.08.2018	8.2272	0.1028
B_RE	24.08.2018	0.0204	0.0041
B_Inner	24.08.2018	0.8656	0.0173
B_NC	24.08.2018	0.0400	0.0050
B_Outer	08.08.2018	1.2656	0.0230
T_Inner	20.08.2018	0.5920	0.0148
T_NC	22.08.2018	0.2416	0.0173
T_RE_Degeer	22.08.2018	0.8480	0.0848
T_RE_Gips	22.08.2018	0.2960	0.0592
T_RE_Sassen	20.08.2018	0.4976	0.0332
T_Outer	22.08.2018	0.7632	0.0191
ME_3	24.08.2018	2.9200	0.0146
IsK	18.08.2018	21.5552	0.0801
IsG	17.08.2018	59.0272	0.2253

Appendix X: Zooplankton species list

Taxon	Phylum	Subphylum	Class	Subclass	Infraclass	Order	Family	Genus	Species
Aglantha digitale (O.F. Müller, 1776)	Cnidaria	-	Hydrozoa	Trachylinae	-	Trachymedusae	Rhopalonematidae	*Aglantha*	***Aglantha digitale***
Alentia gelatinosa (M. Sars, 1835)	Annelida	-	Polychaeta	Errantia	-	Phyllodocida	Polynoidae	*Alentia*	***Alentia gelatinosa***
Beröe cucumis (Fabricius, 1780)	Ctenophora	-	Nuda	-	-	Beroida	Beroidae	*Beroe*	***Beroe cucumis***
Bivalvia (Linnaeus, 1758) (veliger)	Mollusca		Bivalvia			-	-	-	-
Calanoida (Sars G. O., 1903) (nauplii)	Arthropoda	Crustacea	Hexanauplia	Copepoda	Neocopepoda	Calanoida	-	-	-
Calanus spp. (Leach, 1816)	Arthropoda	Crustacea	Hexanauplia	Copepoda	Neocopepoda	Calanoida	Calanidae	*Calanus*	-
Chaetognatha (unidentified)	Chaetognatha	-	-	-	-	-	-	-	-
Cirripedia (Burmeister, 1834)	Arthropoda	Crustacea	Hexanauplia	Thecostraca	Cirripedia	-	-	-	-
Copepoda (Milne Edwards, 1840) (nauplii)	Arthropoda	Crustacea	Hexanauplia	Copepoda	-	-	-	-	-
Dimophyes arctica (Chun, 1897)	Cnidaria	-	Hydrozoa	Hydroidolina	-	Siphonophorae	Diphyidae	*Dimophyes*	***Dimophyes arctica***
Echinodermata (Bruguière, 1792) (larvae)	Echinodermata	-	-	-	-	-	-	-	-
Euphausiidae (Dana, 1852) (juvenile stages)	Arthropoda	Crustacea	Malacostraca	Eumalacostraca	-	Euphausiacea	Euphausiidae	-	-
Fritillaria borealis (Lohmann, 1896)	Chordata	Tunicata	Appendicularia	-	-	Copelata	Fritillariidae	*Fritillaria*	***Fritillaria borealis***
Hyas araneus (Linnaeus, 1758) (larvae)	Arthropoda	Crustacea	Malacostraca	Eumalacostraca	-	Decapoda	Oregoniidae	*Hyas*	***Hyas araneus***
Isopoda (Latreille, 1817) (larvae)	Arthropoda	Crustacea	Malacostraca	Eumalacostraca	-	Isopoda	-	-	-
Limacina helicina (Phipps, 1774) (veliger)	Mollusca	-	Gastropoda	Heterobranchia	Euthyneura	Pteropoda	Limacinidae	*Limacina*	***Limacina helicina***
Mertensia ovum (Fabricius, 1780)	Ctenophora	-	Tentaculata	-	-	Cydippida	Mertensiidae	*Mertensia*	***Mertensia ovum***
Metridia longa (Lubbock, 1854)	Arthropoda	Crustacea	Hexanauplia	Copepoda	Neocopepoda	Calanoida	Metridinidae	*Metridia*	***Metridia longa***
Microcalanus spp. (Sars g. O., 1903)	Arthropoda	Crustacea	Hexanauplia	Copepoda	Neocopepoda	Calanoida	Clausocalanidae	*Microcalanus*	-
Microsetella norvegica (Boeck, 1865)	Arthropoda	Crustacea	Hexanauplia	Copepoda	Neocopepoda	Harpacticoida	Ectinosomatidae	*Microsetella*	***Microsetella norvegica***
Oikopleura spp. (Mertens, 1830)	Chordata	Tunicata	Appendicularia	-	-	Copelata	Oikopleuridae	*Oikopleura*	-
Oithona atlantica (Farran, 1908)	Arthropoda	Crustacea	Hexanauplia	Copepoda	Neocopepoda	Cyclopoida	Oithonidae	*Oithona*	***Oithona atlantica***
Oithona similis (Claus, 1866)	Arthropoda	Crustacea	Hexanauplia	Copepoda	Neocopepoda	Cyclopoida	Oithonidae	*Oithona*	***Oithona similis***
Oncaea spp. (Philippi, 1843) (juvenile)	Arthropoda	Crustacea	Hexanauplia	Copepoda	Neocopepoda	Cyclopoida	Oncaeidae	*Oncaea*	-
Parasagitta elegans (Verrill, 1873)	Chaetognatha	-	Sagittoidea	-	-	Aphragmophora	Sagittidae	*Parasigitta*	***Parasigitta elegans***
Polychaeta (Grube, 1850) (juvenile)	Annelida	-	Polychaeta	-	-	-	-	-	-
Pseudocalanus spp. (Boeck, 1872)	Arthropoda	Crustacea	Hexanauplia	Copepoda	Neocopepoda	Calanoida	Clausocalanidae	*Pseudocalanus*	-
Themisto abyssorum (Boeck, 1871)	Arthropoda	Crustacea	Malacostraca	Eumalacostraca	-	Amphipoda	Hyperiidae	*Themisto*	***Themisto abyssorum***
Thysanoessa inermis (Krøyer, 1846)	Arthropoda	Crustacea	Malacostraca	Eumalacostraca	-	Euphausiacea	Euphausiidae	*Thysanoessa*	***Thysanoessa inermis***
Triconia borealis (Sars G. O., 1918)	Arthropoda	Crustacea	Hexanauplia	Copepoda	Neocopepoda	Cyclopoida	Oncaeidae	*Triconia*	***Triconia borelais***
Trochophore (larvae)	-								
Zoea (larvae)	Arthropoda	Crustacea	Malacostraca	Eumalacostraca	-	Decapoda	-	-	-

Appendix XI: R- Scripts

Physical and environmental parameters

```
#Downloading data

Env_doc<- read.csv("Env_doc.csv", sep = ";", header = T)
Env_doc_may<-Env_doc[1:14,]
Env_doc_june<-Env_doc[15:31,]
Env_doc_aug<-Env_doc[32:48,]

#Packages

library("ggplot2")
library("tidyverse")

#Sorting of data

Env_doc$Type3 <- factor(Env_doc$Type3, c("Estuary", "Inner", "Outer", "Marine"))

Month_names <- list(
    '1_May'="May",
    '2_June'="June",
    '3_August'="August"
  )
Month_labeller <- function(variable,value){
  return(Month_names[value])
}

#ENVIRONMENTAL PARAMETERS:

#TEMPERATURE - SURFACE

#Environmental plot:

Temp_plot <-ggplot(Env_doc, aes(x=Type3, y=Temp_surface)) +
  stat_boxplot(geom ='errorbar', width = 0.1, linetype = 1) +
  geom_boxplot(aes(fill=Type3), alpha=0.2)+theme_classic()+theme(text = element_text(size=18))
+
  geom_point(aes(fill=Type3, shape=Fjord, group=Type3), color="black", alpha  =0.9, size=6,
stroke=0.8, position = position_jitterdodge(jitter.width = 0, dodge.width = 0.8)) +
  facet_grid((. ~ Month), labeller=Month_labeller) +
  theme_bw() +
  theme(panel.grid.major = element_blank(),
        panel.grid.minor = element_blank(),
        strip.background = element_rect(fill = "gray88", colour = "black"),
        panel.border = element_rect(colour = "black")) +
  theme(plot.title = element_text(size=20, margin=margin(t=20, b=20)),
        legend.text = element_text(size = 30),
        legend.title = element_text(size = 30),
        legend.key = element_rect(size = 5),
        legend.key.size = unit(1.8, 'lines'),
        axis.title.x = element_text(hjust=0.5, size = 30),
        axis.title.y = element_text(size = 30),
        axis.text.y = element_text(hjust=0.5, size = 24),
        strip.text.x = element_text(size = 25, colour = "black"),
        axis.text.x = element_text(hjust=1, size = 22, angle = 45)) +
  scale_shape_manual (values = c(21,22,23,24)) +
  scale_fill_manual(values=c("lightsalmon4","cornsilk","lightblue3","blue"), name = "Type3",
labels = c("Estuary", "Inner", "Outer", "Marine")) +
  scale_x_discrete(breaks=c("Estuary", "Inner", "Outer", "Marine"),
                   labels=c("Estuary", "Inner", "Outer", "Marine")) +
  xlab("Habitat category")+
  ylab(expression(paste("Temperature ", (~degree~C)))) +
  guides(fill = FALSE) #guide_legend(override.aes = list(shape = 21) ) )

Temp_plot

#Statistics:

#Testing for normality:
shapiro.test(Env_doc$Temp_surface) #W = 0.93928, p-value = 0.01522
shapiro.test(Env_doc_may$Temp_surface) #W = 0.96863, p-value = 0.8578
shapiro.test(Env_doc_june$Temp_surface) #W = 0.95453, p-value = 0.532
```

```
shapiro.test(Env_doc_aug$Temp_surface) #W = 0.97435, p-value = 0.8891

#Kruskall-Wallis
kruskal.test(Temp_surface ~ Month, data = Env_doc) #Kruskal-Wallis chi-squared = 40.172, df =
2, p-value = 1.891e-09

#ANOVA:
aov_temp_may<- aov(Env_doc_may$Temp_surface ~ Env_doc_may$Type3)
summary(aov_temp_may) #p=0.677
aov_temp_june<- aov(Env_doc_june$Temp_surface ~ Env_doc_june$Type3)
summary(aov_temp_june) #p=0.217
aov_temp_aug<- aov(Env_doc_aug$Temp_surface ~ Env_doc_aug$Type3)
summary(aov_temp_aug) #p=0.979
```

#TEMPERATURE - 15M

```
#Environmental plot:

Temp_15_plot <-ggplot(Env_doc, aes(x=Type3, y=Temp_15m)) +
  stat_boxplot(geom ='errorbar', width = 0.1, linetype = 1) +
  geom_boxplot(aes(fill=Type3), alpha=0.2)+theme_classic()+theme(text = element_text(size=18))
+
  geom_point(aes(fill=Type3, shape=Fjord, group=Type3), color="black", alpha  =0.9, size=6,
stroke=0.8, position = position_jitterdodge(jitter.width = 0, dodge.width = 0.8)) +
  facet_grid((. ~ Month), labeller=Month_labeller) +
  theme_bw() +
  theme(panel.grid.major = element_blank(),
        panel.grid.minor = element_blank(),
        strip.background = element_rect(fill = "gray88", colour = "black"),
        panel.border = element_rect(colour = "black")) +
  theme(plot.title = element_text(size=20, margin=margin(t=20, b=20)),
        legend.text = element_text(size = 30),
        legend.title = element_text(size = 30),
        legend.key = element_rect(size = 5),
        legend.key.size = unit(1.8, 'lines'),
        axis.title.x = element_text(hjust=0.5, size = 30),
        axis.title.y = element_text(size = 30),
        axis.text.y = element_text(hjust=0.5, size = 24),
        strip.text.x = element_text(size = 25, colour = "black"),
        axis.text.x = element_text(hjust=1, size = 22, angle = 45)) +
  scale_shape_manual (values = c(21,22,23,24)) +
  scale_fill_manual(values=c("lightsalmon4","cornsilk","lightblue3","blue"), name = "Type3",
labels = c("Estuary", "Inner", "Outer", "Marine")) +
  scale_x_discrete(breaks=c("Estuary", "Inner", "Outer", "Marine"),
                   labels=c("Estuary", "Inner", "Outer", "Marine")) +
  xlab("Habitat category")+
  ylab(expression(paste("Temperature ", (~degree~C)))) +
  guides(fill = FALSE) #guide_legend(override.aes = list(shape = 21) ) )

Temp_15_plot
```

#SALINITY - SURFACE

```
#Environmental plot:

Salinity_plot <-ggplot(Env_doc, aes(x=Type3, y=Salinity_surface)) +
  stat_boxplot(geom ='errorbar', width = 0.1, linetype = 1) +
  geom_boxplot(aes(fill=Type3), alpha=0.2)+theme_classic()+theme(text = element_text(size=18))
+
  geom_point(aes(fill=Type3, shape=Fjord, group=Type3), color="black", alpha  =0.9, size=6,
stroke=0.8, position = position_jitterdodge(jitter.width = 0, dodge.width = 0.8)) +
  facet_grid((. ~ Month), labeller=Month_labeller) +
  theme_bw() +
  theme(panel.grid.major = element_blank(),
        panel.grid.minor = element_blank(),
        strip.background = element_rect(fill = "gray88", colour = "black"),
        panel.border = element_rect(colour = "black")) +
  theme(plot.title = element_text(size=20, margin=margin(t=20, b=20)),
        legend.text = element_text(size = 30),
        legend.title = element_text(size = 30),
        legend.key = element_rect(size = 5),
        legend.key.size = unit(1.8, 'lines'),
        axis.title.x = element_text(hjust=0.5, size = 30),
        axis.title.y = element_text(size = 30),
        axis.text.y = element_text(hjust=0.5, size = 24),
```

```
        strip.text.x = element_text(size = 25, colour = "black"),
        axis.text.x = element_text(hjust=1, size = 22, angle = 45)) +
  scale_shape_manual (values = c(21,22,23,24)) +
  scale_fill_manual(values=c("lightsalmon4","cornsilk","lightblue3","blue"), name = "Type3",
labels = c("Estuary", "Inner", "Outer", "Marine")) +
  scale_x_discrete(breaks=c("Estuary", "Inner", "Outer", "Marine"),
                   labels=c("Estuary", "Inner", "Outer", "Marine")) +
  xlab("Habitat category")+
  ylab("Salinity (PSU)") +
  guides(fill = FALSE) #guide_legend(override.aes = list(shape = 21) ) )

Salinity_plot

#Statistics:

#Testing for normality:
shapiro.test(Env_doc$Salinity_surface) #W = 0.62612, p-value = 8.138e-10
shapiro.test(Env_doc_may$Salinity_surface) #W = 0.91671, p-value = 0.1972
shapiro.test(Env_doc_june$Salinity_surface) #W = 0.57522, p-value = 6.05e-06
shapiro.test(Env_doc_aug$Salinity_surface) #W = 0.79804, p-value = 0.001907

#Kruskall-Wallis
kruskal.test(Salinity_surface ~ Month, data = Env_doc) #Kruskal-Wallis chi-squared = 10.309,
df = 2, p-value = 0.005773
kruskal.test(Salinity_surface ~ Type3, data = Env_doc_june) #Kruskal-Wallis chi-squared =
8.7951, df = 3, p-value = 0.03214
kruskal.test(Salinity_surface ~ Type3, data = Env_doc_aug) #Kruskal-Wallis chi-squared =
5.3542, df = 3, p-value = 0.1476

#ANOVA:
aov_salinity_may<- aov(Env_doc_may$Salinity_surface ~ Env_doc_may$Type3)
summary(aov_salinity_may)
```

#SALINITY - 15M

```
#Environmental plot:

Salinity_15_plot <-ggplot(Env_doc, aes(x=Type3, y=Salinity_15m)) +
  stat_boxplot(geom ='errorbar', width = 0.1, linetype = 1) +
  geom_boxplot(aes(fill=Type3), alpha=0.2)+theme_classic()+theme(text = element_text(size=18))
+
  geom_point(aes(fill=Type3, shape=Fjord, group=Type3), color="black", alpha  =0.9, size=6,
stroke=0.8, position = position_jitterdodge(jitter.width = 0, dodge.width = 0.8)) +
  facet_grid((. ~ Month), labeller=Month_labeller) +
  theme_bw() +
  theme(panel.grid.major = element_blank(),
        panel.grid.minor = element_blank(),
        strip.background = element_rect(fill = "gray88", colour = "black"),
        panel.border = element_rect(colour = "black")) +
  theme(plot.title = element_text(size=20, margin=margin(t=20, b=20)),
        legend.text = element_text(size = 30),
        legend.title = element_text(size = 30),
        legend.key = element_rect(size = 5),
        legend.key.size = unit(1.8, 'lines'),
        axis.title.x = element_text(hjust=0.5, size = 30),
        axis.title.y = element_text(size = 30),
        axis.text.y = element_text(hjust=0.5, size = 24),
        strip.text.x = element_text(size = 25, colour = "black"),
        axis.text.x = element_text(hjust=1, size = 22, angle = 45)) +
  scale_shape_manual (values = c(21,22,23,24)) +
  scale_fill_manual(values=c("lightsalmon4","cornsilk","lightblue3","blue"), name = "Type3",
labels = c("Estuary", "Inner", "Outer", "Marine")) +
  scale_x_discrete(breaks=c("Estuary", "Inner", "Outer", "Marine"),
                   labels=c("Estuary", "Inner", "Outer", "Marine")) +
  xlab("Habitat category")+
  ylab("Salinity (PSU)") +
  guides(fill = FALSE) #guide_legend(override.aes = list(shape = 21) ) )

Salinity_15_plot
```

#TURBIDITY - SURFACE

```
#Environmental plot:

Turbidity_plot <-ggplot(Env_doc, aes(x=Type3, y=Turbidity_surface)) +
```

```
  stat_boxplot(geom ='errorbar', width = 0.1, linetype = 1) +
  geom_boxplot(aes(fill=Type3), alpha=0.2)+theme_classic()+theme(text = element_text(size=18))
+
  geom_point(aes(fill=Type3, shape=Fjord, group=Type3), color="black", alpha  =0.9, size=6,
stroke=0.8, position = position_jitterdodge(jitter.width = 0, dodge.width = 0.8)) +
  facet_grid((. ~ Month), labeller=Month_labeller) +
  theme_bw() +
  theme(panel.grid.major = element_blank(),
        panel.grid.minor = element_blank(),
        strip.background = element_rect(fill = "gray88", colour = "black"),
        panel.border = element_rect(colour = "black")) +
  theme(plot.title = element_text(size=20, margin=margin(t=20, b=20)),
        legend.text = element_text(size = 30),
        legend.title = element_text(size = 30),
        legend.key = element_rect(size = 5),
        legend.key.size = unit(1.8, 'lines'),
        axis.title.x = element_text(hjust=0.5, size = 30),
        axis.title.y = element_text(size = 30),
        axis.text.y = element_text(hjust=0.5, size = 24),
        strip.text.x = element_text(size = 25, colour = "black"),
        axis.text.x = element_text(hjust=1, size = 22, angle = 45)) +
  scale_shape_manual (values = c(21,22,23,24)) +
  scale_fill_manual(values=c("lightsalmon4","cornsilk","lightblue3","blue"), name = "Type3",
labels = c("Estuary", "Inner", "Outer", "Marine")) +
  scale_x_discrete(breaks=c("Estuary", "Inner", "Outer", "Marine"),
                   labels=c("Estuary", "Inner", "Outer", "Marine")) +
  xlab("Habitat category")+
  ylab("Turbidity (NTU) (log)") +
  guides(fill = FALSE) + #guide_legend(override.aes = list(shape = 21) ) ) +
  scale_y_log10()

Turbidity_plot

#Statistics:

#Testing for normality:
shapiro.test(Env_doc$Turbidity_surface) #W = 0.30116, p-value = 9.067e-14 = No normality
shapiro.test(Env_doc_may$Turbidity_surface) #W = 0.75305, p-value = 0.001388
shapiro.test(Env_doc_june$Turbidity_surface) #W = 0.66746, p-value = 5.062e-05
shapiro.test(Env_doc_aug$Turbidity_surface) #W = 0.44044, p-value = 4.211e-07

#Kruskall-Wallis
kruskal.test(Turbidity_surface ~ Month, data = Env_doc) #Kruskal-Wallis chi-squared = 13.736,
df = 2, p-value = 0.00104

#ANOVA:
may_turbidity<- aov(Env_doc_may$Turbidity_surface ~ Env_doc_may$Type3)
summary(may_turbidity) #p=0.138 not significant
june_turbidity<- aov(Env_doc_june$Turbidity_surface ~ Env_doc_june$Type3)
summary(june_turbidity) #p=0.398 not significant
aug_turbidity<- aov(Env_doc_aug$Turbidity_surface ~ Env_doc_aug$Type3)
summary(aug_turbidity) #p=0.172 not significant


#TURBIDITY - SURFACE

#Environmental plot:

Turbidity_15_plot <-ggplot(Env_doc, aes(x=Type3, y=Turbidity_15m)) +
  stat_boxplot(geom ='errorbar', width = 0.1, linetype = 1) +
  geom_boxplot(aes(fill=Type3), alpha=0.2)+theme_classic()+theme(text = element_text(size=18))
+
  geom_point(aes(fill=Type3, shape=Fjord, group=Type3), color="black", alpha  =0.9, size=6,
stroke=0.8, position = position_jitterdodge(jitter.width = 0, dodge.width = 0.8)) +
  facet_grid((. ~ Month), labeller=Month_labeller) +
  theme_bw() +
  theme(panel.grid.major = element_blank(),
        panel.grid.minor = element_blank(),
        strip.background = element_rect(fill = "gray88", colour = "black"),
        panel.border = element_rect(colour = "black")) +
  theme(plot.title = element_text(size=20, margin=margin(t=20, b=20)),
        legend.text = element_text(size = 30),
        legend.title = element_text(size = 30),
        legend.key = element_rect(size = 5),
        legend.key.size = unit(1.8, 'lines'),
        axis.title.x = element_text(hjust=0.5, size = 30),
        axis.title.y = element_text(size = 30),
```

```
        axis.text.y = element_text(hjust=0.5, size = 24),
        strip.text.x = element_text(size = 25, colour = "black"),
        axis.text.x = element_text(hjust=1, size = 22, angle = 45)) +
  scale_shape_manual (values = c(21,22,23,24)) +
  scale_fill_manual(values=c("lightsalmon4","cornsilk","lightblue3","blue"), name = "Type3",
labels = c("Estuary", "Inner", "Outer", "Marine")) +
  scale_x_discrete(breaks=c("Estuary", "Inner", "Outer", "Marine"),
                   labels=c("Estuary", "Inner", "Outer", "Marine")) +
  xlab("Habitat category")+
  ylab("Turbidity (NTU) (log)") +
  guides(fill = FALSE) + #guide_legend(override.aes = list(shape = 21) ) ) +
  scale_y_log10()

Turbidity_15_plot
```

#SECCHI DEPTH

```
#Environmental plot:

Secchi_plot <-ggplot(Env_doc, aes(x=Type3, y=Secchi_depth)) +
  stat_boxplot(geom ='errorbar', width = 0.1, linetype = 1) +
  geom_boxplot(aes(fill=Type3), alpha=0.2)+theme_classic()+theme(text = element_text(size=18))
+
  geom_point(aes(fill=Type3, shape=Fjord, group=Type3), color="black", alpha  =0.9, size=6,
stroke=0.8, position = position_jitterdodge(jitter.width = 0, dodge.width = 0.8)) +
  facet_grid((. ~ Month), labeller=Month_labeller) +
  theme_bw() +
  theme(panel.grid.major = element_blank(),
        panel.grid.minor = element_blank(),
        strip.background = element_rect(fill = "gray88", colour = "black"),
        panel.border = element_rect(colour = "black")) +
  theme(plot.title = element_text(size=20, margin=margin(t=20, b=20)),
        legend.text = element_text(size = 30),
        legend.title = element_text(size = 30),
        legend.key = element_rect(size = 5),
        legend.key.size = unit(1.8, 'lines'),
        axis.title.x = element_text(hjust=0.5, size = 30),
        axis.title.y = element_text(size = 30),
        axis.text.y = element_text(hjust=0.5, size = 24),
        strip.text.x = element_text(size = 25, colour = "black"),
        axis.text.x = element_text(hjust=1, size = 22, angle = 45)) +
  scale_shape_manual (values = c(21,22,23,24)) +
  scale_fill_manual(values=c("lightsalmon4","cornsilk","lightblue3","blue"), name = "Type3",
labels = c("Estuary", "Inner", "Outer", "Marine")) +
  scale_x_discrete(breaks=c("Estuary", "Inner", "Outer", "Marine"),
                   labels=c("Estuary", "Inner", "Outer", "Marine")) +
  xlab("Habitat category")+
  ylab("Secchi depth (m)") +
  guides(fill = FALSE) #guide_legend(override.aes = list(shape = 21) ) )

Secchi_plot

#Statistics:

#Testing for normality:
shapiro.test(Env_doc$Secchi_depth) #W = 0.9318, p-value = 0.007951
shapiro.test(Env_doc_june$Secchi_depth) #W = 0.82182, p-value = 0.004105
shapiro.test(Env_doc_aug$Secchi_depth) #W = 0.94491, p-value = 0.3812

#Kruskall-Wallis
kruskal.test(Secchi_depth ~ Month, data = Env_doc) #Kruskal-Wallis chi-squared = 23.21, df =
2, p-value = 9.119e-06
kruskal.test(Secchi_depth ~ Type3, data = Env_doc_june) #Kruskal-Wallis chi-squared = 9.7116,
df = 3, p-value = 0.02118

#ANOVA:
aov_secchi_aug<- aov(Env_doc_aug$Secchi_depth ~ Env_doc_aug$Type3)
summary(aov_secchi_aug)
```

#ZOOPLANKTON PARAMETERS:

#SHANNON - WIENER DIVERSITY INDEX

```
#Plot:
```

```
SW_plot <-ggplot(Env_doc, aes(x=Type3, y=Shannon_wiener_m3)) +
  stat_boxplot(geom ='errorbar', width = 0.1, linetype = 1) +
  geom_boxplot(aes(fill=Type3), alpha=0.2)+theme_classic()+theme(text = element_text(size=18))
+
  geom_point(aes(fill=Type3, shape=Fjord, group=Type3), color="black", alpha  =0.9, size=6,
stroke=0.8, position = position_jitterdodge(jitter.width = 0, dodge.width = 0.8)) +
  facet_grid((. ~ Month), labeller=Month_labeller) +
  theme_bw() +
  theme(panel.grid.major = element_blank(),
        panel.grid.minor = element_blank(),
        strip.background = element_rect(fill = "gray88", colour = "black"),
        panel.border = element_rect(colour = "black")) +
  theme(plot.title = element_text(size=20, margin=margin(t=20, b=20)),
        legend.text = element_text(size = 30),
        legend.title = element_text(size = 30),
        legend.key = element_rect(size = 5),
        legend.key.size = unit(1.8, 'lines'),
        axis.title.x = element_text(hjust=0.5, size = 30),
        axis.title.y = element_text(size = 30),
        axis.text.y = element_text(hjust=0.5, size = 24),
        strip.text.x = element_text(size = 25, colour = "black"),
        axis.text.x = element_text(hjust=1, size = 22, angle = 45)) +
  scale_shape_manual (values = c(21,22,23,24)) +
  scale_fill_manual(values=c("lightsalmon4","cornsilk","lightblue3","blue"), name = "Type3",
labels = c("Estuary", "Inner", "Outer", "Marine")) +
  scale_x_discrete(breaks=c("Estuary", "Inner", "Outer", "Marine"),
                   labels=c("Estuary", "Inner", "Outer", "Marine")) +
  xlab("Habitat category")+
  ylab("Shannon-Wiener Diversity Index")+
  guides(fill = FALSE) #guide_legend(override.aes = list(shape = 21) ) )

SW_plot

#Statistics:

#Testing for normality:
shapiro.test(Env_doc$Shannon_wiener_m3) #W = 0.96547, p-value = 0.1769
shapiro.test(Env_doc_may$Shannon_wiener_m3) #W = 0.88138, p-value = 0.06081
shapiro.test(Env_doc_june$Shannon_wiener_m3) #W = 0.94173, p-value = 0.3392
shapiro.test(Env_doc_aug$Shannon_wiener_m3) #W = 0.89444, p-value = 0.06551

#Kruskall-Wallis
kruskal.test(Shannon_wiener_m3 ~ Month, data = Env_doc)

#ANOVA:
aov_SW<- aov(Env_doc$Shannon_wiener_m3 ~ Env_doc$Month) #p=0.43
summary(aov_SW)
aov_SW_may<- aov(Env_doc_may$Shannon_wiener_m3 ~ Env_doc_may$Type3) #p=0.002
summary(aov_SW_may)
aov_SW_june<- aov(Env_doc_june$Shannon_wiener_m3 ~ Env_doc_june$Type3) #p=0.016
summary(aov_SW_june)
aov_SW_aug<- aov(Env_doc_aug$Shannon_wiener_m3 ~ Env_doc_aug$Type3) #p=0.0106
summary(aov_SW_aug)


#SPECIES RICHNESS

#Plot:

Richness_plot <-ggplot(Env_doc, aes(x=Type3, y=Species_diversity_m3)) +
  stat_boxplot(geom ='errorbar', width = 0.1, linetype = 1) +
  geom_boxplot(aes(fill=Type3), alpha=0.2)+theme_classic()+theme(text = element_text(size=18))
+
  geom_point(aes(fill=Type3, shape=Fjord, group=Type3), color="black", alpha  =0.9, size=6,
stroke=0.8, position = position_jitterdodge(jitter.width = 0, dodge.width = 0.8)) +
  facet_grid((. ~ Month), labeller=Month_labeller) +
  theme_bw() +
  theme(panel.grid.major = element_blank(),
        panel.grid.minor = element_blank(),
        strip.background = element_rect(fill = "gray88", colour = "black"),
        panel.border = element_rect(colour = "black")) +
  theme(plot.title = element_text(size=20, margin=margin(t=20, b=20)),
        legend.text = element_text(size = 30),
        legend.title = element_text(size = 30),
        legend.key = element_rect(size = 5),
        legend.key.size = unit(1.8, 'lines'),
        axis.title.x = element_text(hjust=0.5, size = 30),
```

```
        axis.title.y = element_text(size = 30),
        axis.text.y = element_text(hjust=0.5, size = 24),
        strip.text.x = element_text(size = 25, colour = "black"),
        axis.text.x = element_text(hjust=1, size = 22, angle = 45)) +
  scale_shape_manual (values = c(21,22,23,24)) +
  scale_fill_manual(values=c("lightsalmon4","cornsilk","lightblue3","blue"), name = "Type3",
labels = c("Estuary", "Inner", "Outer", "Marine")) +
  scale_x_discrete(breaks=c("Estuary", "Inner", "Outer", "Marine"),
                   labels=c("Estuary", "Inner", "Outer", "Marine")) +
  xlab("Habitat category")+
  ylab("Number of taxa")+
  guides(fill = FALSE) #guide_legend(override.aes = list(shape = 21) ) )

Richness_plot

#Statistics:

#Testing for normality:
shapiro.test(Env_doc$Species_diversity_m3) #W = 0.85383, p-value = 2.752e-05
shapiro.test(Env_doc_may$Species_diversity_m3) #W = 0.88042, p-value = 0.05892
shapiro.test(Env_doc_june$Species_diversity_m3) #W = 0.96035, p-value = 0.6382
shapiro.test(Env_doc_aug$Species_diversity_m3) #W = 0.85134, p-value = 0.01124

#Kruskall-Wallis
kruskal.test(Species_diversity_m3 ~ Type3, data = Env_doc_aug) #Kruskal-Wallis chi-squared =
9.9101, df = 3, p-value = 0.01935

#ANOVA:
aov_richness_may<- aov(Env_doc_may$Species_diversity_m3 ~ Env_doc_may$Type3)
summary(aov_richness_may) #p=0.096
aov_richness_june<- aov(Env_doc_june$Species_diversity_m3 ~ Env_doc_june$Type3)
summary(aov_richness_june) #p=0.324


#BIOMASS m3

#Order names

biomass_m2_names  <- c(
  `1_May` = "May",
  `2_June` = "June",
  `3_August` = "August")

#Plot:

Biomass_m3_plot <-ggplot(Env_doc, aes(x=Type3, y=Biomass_dw_per_m3)) +
  stat_boxplot(geom ='errorbar', width = 0.1, linetype = 1) +
  geom_boxplot(aes(fill=Type3), alpha=0.2)+theme_classic()+theme(text = element_text(size=18))
+
  geom_point(aes(fill=Type3, shape=Fjord, group=Type3), color="black", alpha  =0.9, size=6,
stroke=0.8, position = position_jitterdodge(jitter.width = 0, dodge.width = 0.8)) +
  facet_grid((. ~ Month), labeller=Month_labeller) +
  theme_bw() +
  theme(panel.grid.major = element_blank(),
        panel.grid.minor = element_blank(),
        strip.background = element_rect(fill = "gray88", colour = "black"),
        panel.border = element_rect(colour = "black")) +
  theme(plot.title = element_text(size=20, margin=margin(t=20, b=20)),
        legend.text = element_text(size = 30),
        legend.title = element_text(size = 30),
        legend.key = element_rect(size = 5),
        legend.key.size = unit(1.8, 'lines'),
        axis.title.x = element_text(hjust=0.5, size = 30),
        axis.title.y = element_text(size = 30),
        axis.text.y = element_text(hjust=0.5, size = 24),
        strip.text.x = element_text(size = 25, colour = "black"),
        axis.text.x = element_text(hjust=1, size = 22, angle = 45)) +
  scale_shape_manual (values = c(21,22,23,24)) +
  scale_fill_manual(values=c("lightsalmon4","cornsilk","lightblue3","blue"), name = "Type3",
labels = c("Estuary", "Inner", "Outer", "Marine")) +
  scale_x_discrete(breaks=c("Estuary", "Inner", "Outer", "Marine"),
                   labels=c("Estuary", "Inner", "Outer", "Marine")) +
  xlab("Habitat category")+
  ylab(expression(paste("Dry weight, g m"^{-3})))+
  guides(fill = FALSE) #guide_legend(override.aes = list(shape = 21) ) )

Biomass_m3_plot
```

```
#Statistics:

#Testing for normality:
shapiro.test(Env_doc$Biomass_dw_per_m3) #W = 0.71911, p-value = 2.934e-08
shapiro.test(Env_doc_may$Biomass_dw_per_m3) #W = 0.8272, p-value = 0.01105
shapiro.test(Env_doc_june$Biomass_dw_per_m3) #W = 0.85501, p-value = 0.0128
shapiro.test(Env_doc_aug$Biomass_dw_per_m3) #W = 0.69459, p-value = 0.0001004

#Kruskall-Wallis
kruskal.test(Biomass_dw_per_m3 ~ Month, data = Env_doc) #Kruskal-Wallis chi-squared = 4.4751,
df = 2, p-value = 0.1067
kruskal.test(Biomass_dw_per_m3 ~ Type3, data = Env_doc_may) #Kruskal-Wallis chi-squared =
7.4762, df = 3, p-value = 0.05817
kruskal.test(Biomass_dw_per_m3 ~ Type3, data = Env_doc_june) #Kruskal-Wallis chi-squared =
7.319, df = 3, p-value = 0.0624
kruskal.test(Biomass_dw_per_m3 ~ Type3, data = Env_doc_aug) #Kruskal-Wallis chi-squared =
2.6163, df = 3, p-value = 0.4546
```

#BIOMASS m2

```
#Order names:

biomass_m2_names  <- c(
  `1_May` = "May",
  `2_June` = "June",
  `3_August` = "August")

#Plot:

Biomass_m2_plot <-ggplot(Env_doc, aes(x=Type3, y=Biomass_dw_per_m2)) +
  stat_boxplot(geom ='errorbar', width = 0.1, linetype = 1) +
  geom_boxplot(aes(fill=Type3), alpha=0.2)+theme_classic()+theme(text = element_text(size=18))
+
  geom_point(aes(fill=Type3, shape=Fjord, group=Type3), color="black", alpha  =0.9, size=6,
stroke=0.8, position = position_jitterdodge(jitter.width = 0, dodge.width = 0.8)) +
  facet_grid((. ~ Month), labeller=Month_labeller) +
  theme_bw() +
  theme(panel.grid.major = element_blank(),
        panel.grid.minor = element_blank(),
        strip.background = element_rect(fill = "gray88", colour = "black"),
        panel.border = element_rect(colour = "black")) +
  theme(plot.title = element_text(size=20, margin=margin(t=20, b=20)),
        legend.text = element_text(size = 30),
        legend.title = element_text(size = 30),
        legend.key = element_rect(size = 5),
        legend.key.size = unit(1.8, 'lines'),
        axis.title.x = element_text(hjust=0.5, size = 30),
        axis.title.y = element_text(size = 30),
        axis.text.y = element_text(hjust=0.5, size = 24),
        strip.text.x = element_text(size = 25, colour = "black"),
        axis.text.x = element_text(hjust=1, size = 22, angle = 45)) +
  scale_shape_manual (values = c(21,22,23,24)) +
  scale_fill_manual(values=c("lightsalmon4","cornsilk","lightblue3","blue"), name = "Type3",
labels = c("Estuary", "Inner", "Outer", "Marine")) +
  scale_x_discrete(breaks=c("Estuary", "Inner", "Outer", "Marine"),
                   labels=c("Estuary", "Inner", "Outer", "Marine")) +
  xlab("Habitat category")+
  ylab(expression(paste("Dry weight, g m"^{-2})))+
  guides(fill = FALSE) #guide_legend(override.aes = list(shape = 21) ) )

Biomass_m2_plot
```

Zooplankton data

#Download data

```
allspecies <- read.csv("Abundance_all_withcopepodites.csv", sep = ";", header = T)
holo_facet <- read.csv("Abundance_holomero.csv", sep = ";", header = T)
trophic <- read.csv("Trophic_zoo.csv", sep = ";", header = T)
predator <- read.csv("Relative_abundance_predators.csv", sep = ";", header = T)
predator_edit <- read.csv("Relative_abundance_predators_no_zeros.csv", sep = ";", header = T)
meroplankton <- read.csv("Relative_abundance_meroplankton.csv", sep = ";", header = T)
```

```
holoplankton <- read.csv("Abundance_holoplankton.csv", sep = ";", header = T)

#Packages

library(ggplot2)

#All species - Relative abundance

test.df1 <- aggregate(allspecies,
                      by= list(allspecies$Type, allspecies$Species_group, allspecies$Month),
                      FUN= mean)

test.df1$Group.1 <- factor(test.df1$Group.1, c("Estuary","Inner", "Outer", "Marine"))
test.df1$Group.3 <- factor(test.df1$Group.3, c("May", "June", "August"))

all_species_relative <- ggplot(data=test.df1, aes(x=Group.1, y=Relative_abundance,
fill=Group.2)) +
  geom_bar(colour="black", size=0.3, stat="identity", width=0.5) +
  facet_grid(~Group.3) +
  labs(x="Habitat category", y="Relative abundance") +
  theme_bw() +
  theme(panel.grid.major = element_blank(),
        panel.grid.minor = element_blank(),
        strip.background = element_rect(fill = "gray88", colour = "black"),
        panel.border = element_rect(colour = "black")) +
  theme(plot.title = element_text(size=20, margin=margin(t=20, b=20)),
        legend.text = element_text(size = 25),
        legend.title = element_blank(),
        legend.position="bottom",
        axis.title.x = element_text(size = 30),
        axis.text.y = element_text(hjust=0.5, size = 24),
        axis.title.y = element_text(size = 30),
        axis.text.x = element_text(hjust=1, size = 22, angle = 45),
        strip.text.x = element_text(size = 25, colour = "black")) +
  scale_fill_brewer(palette="Accent",
                    labels=c("Copepoda nauplii","Copepodite stages","Large copepods",
"Meroplankton", "Other", "Small copepods")) +
  scale_colour_manual(palette="Accent") +
  theme(plot.title = element_text(size=20, margin=margin(t=20, b=20)))

all_species_relative

#All species - Total abundance - m3

test.df2 <- aggregate(allspecies,
                      by= list(allspecies$Type, allspecies$Species_group, allspecies$Month),
                      FUN= mean)

test.df2$Group.1 <- factor(test.df2$Group.1, c("Estuary", "Inner", "Outer", "Marine"))
test.df2$Group.3 <- factor(test.df2$Group.3, c("May", "June", "August"))

all_species_total <- ggplot(data=test.df2, aes(x=Group.1, y=Abundance_per_m3, fill=Group.2)) +
  geom_bar(colour="black", size=0.3, stat="identity", width=0.5) +
  facet_grid(~Group.3) +
  labs(x="Habitat category", y=expression(paste("Individuals m"^{-3})), fill="Zooplankton
group") +
  theme_bw() +
  theme(panel.grid.major = element_blank(),
        panel.grid.minor = element_blank(),
        strip.background = element_rect(fill = "gray88", colour = "black"),
        panel.border = element_rect(colour = "black")) +
  theme(plot.title = element_text(size=20, margin=margin(t=20, b=20)),
        legend.text = element_text(size = 25),
        legend.title = element_blank(),
        legend.position="bottom",
        axis.title.x = element_text(size = 30),
        axis.text.y = element_text(hjust=0.5, size = 24),
        axis.title.y = element_text(size = 30),
        axis.text.x = element_text(hjust=1, size = 22, angle = 45),
        strip.text.x = element_text(size = 25, colour = "black")) +
  scale_fill_brewer(palette="Accent",
                    labels=c("Copepoda nauplii", "Copepodite stages", "Large copepods",
"Meroplankton", "Other", "Small copepods")) +
  scale_colour_manual(palette="Accent") +
  theme(plot.title = element_text(size=20, margin=margin(t=20, b=20)))

all_species_total
```

```
#Meroplankton - Relative abundance

test <- aggregate(meroplankton,
                      by= list(meroplankton$Type, meroplankton$Species_group,
meroplankton$Month),
                      FUN= mean)

test$Group.3 <- factor(test$Group.3, c("May", "June", "August"))
test$Group.1 <- factor(test$Group.1, c("Estuary","Inner", "Outer", "Marine"))

mero <- ggplot(data=test, aes(x=Group.1, y=Relative_abundance, fill=Group.2)) +
  geom_bar(colour="black", size=0.3, stat="identity", width=0.5) +
  facet_grid(~Group.3) +
  labs(x="Habitat category", y="Relative abundance") + #fill="Zooplankton group"
  theme_bw() +
  theme(panel.grid.major = element_blank(),
        panel.grid.minor = element_blank(),
        strip.background = element_rect(fill = "gray88", colour = "black"),
        panel.border = element_rect(colour = "black")) +
  theme(plot.title = element_text(size=20, margin=margin(t=20, b=20)),
        legend.text = element_text(size = 25),
        legend.title = element_blank(),
       # legend.position="bottom",
        axis.title.x = element_text(size = 30),
        axis.text.y = element_text(hjust=0.5, size = 24),
        axis.title.y = element_text(size = 30),
        axis.text.x = element_text(hjust=1, size = 22, angle = 45),
        strip.text.x = element_text(size = 25, colour = "black")) +
  scale_fill_brewer(palette="Accent",
                    labels=c("B","C","C", "D", "E", "P")) +
  scale_colour_manual(palette="Accent") +
  theme(plot.title = element_text(size=20, margin=margin(t=20, b=20)))

mero

#Meroplankton - Total abundance - m3

test.df11 <- aggregate(meroplankton,
                      by= list(meroplankton$Type, meroplankton$Species_group,
meroplankton$Month),
                      FUN= mean)

test.df11$Group.1 <- factor(test.df11$Group.1, c("Estuary", "Inner", "Outer", "Marine"))
test.df11$Group.3 <- factor(test.df11$Group.3, c("May", "June", "August"))

mero_total <- ggplot(data=test.df11, aes(x=Group.1, y=Abundance, fill=Group.2)) +
  geom_bar(colour="black", size=0.3, stat="identity", width=0.5) +
  facet_grid(~Group.3) +
  labs(x="Habitat category", y=expression(paste("Individuals m"^{-3})), fill="Zooplankton
group") +
  theme_bw() +
  theme(panel.grid.major = element_blank(),
        panel.grid.minor = element_blank(),
        strip.background = element_rect(fill = "gray88", colour = "black"),
        panel.border = element_rect(colour = "black")) +
  theme(plot.title = element_text(size=20, margin=margin(t=20, b=20)),
        legend.text = element_text(size = 25),
        legend.title = element_blank(),
        #legend.position="bottom",
        axis.title.x = element_text(size = 30),
        axis.text.y = element_text(hjust=0.5, size = 24),
        axis.title.y = element_text(size = 30),
        axis.text.x = element_text(hjust=1, size = 22, angle = 45),
        strip.text.x = element_text(size = 25, colour = "black")) +
  scale_fill_brewer(palette="Accent",
                    labels=c("B","C","C", "D", "E", "P")) +
  scale_colour_manual(palette="Accent") +
  theme(plot.title = element_text(size=20, margin=margin(t=20, b=20)))

mero_total

#Holoplankton - Relative abundance

test.df6 <- aggregate(holoplankton,
                      by= list(holoplankton$Type, holoplankton$Species_group,
holoplankton$Month),
```

```
                      FUN= mean)

test.df6$Group.1 <- factor(test.df6$Group.1, c("Estuary","Inner", "Outer", "Marine"))
test.df6$Group.3 <- factor(test.df6$Group.3, c("May", "June", "August"))

holo<- ggplot(data=test.df6, aes(x=Group.1, y=Relative_abundance, fill=Group.2)) +
  geom_bar(colour="black", size=0.3, stat="identity", width=0.5) +
  facet_grid(~Group.3) +
  labs(x="Habitat category", y="Relative abundance") + #fill="Zooplankton group"
  theme_bw() +
  theme(panel.grid.major = element_blank(),
        panel.grid.minor = element_blank(),
        strip.background = element_rect(fill = "gray88", colour = "black"),
        panel.border = element_rect(colour = "black")) +
  theme(plot.title = element_text(size=20, margin=margin(t=20, b=20)),
        legend.text = element_text(size = 15),
        legend.title = element_blank(),
        #legend.position="bottom",
        axis.title.x = element_text(size = 30),
        axis.text.y = element_text(hjust=0.5, size = 24),
        axis.title.y = element_text(size = 30),
        axis.text.x = element_text(hjust=1, size = 22, angle = 45),
        strip.text.x = element_text(size = 25, colour = "black")) +
  scale_fill_brewer(palette="Set3",
                    labels=c("A","C","C", "C", "E", "M", "O", "O", "O", "P")) +
  scale_colour_manual(palette="Set3") +
  theme(plot.title = element_text(size=20, margin=margin(t=20, b=20)))

holo
```

#Holoplankton - Total abundance - m3

```
test.df12 <- aggregate(holoplankton,
                       by= list(holoplankton$Type, holoplankton$Species_group,
holoplankton$Month),
                       FUN= mean)

test.df12$Group.1 <- factor(test.df12$Group.1, c("Estuary", "Inner", "Outer", "Marine"))
test.df12$Group.3 <- factor(test.df12$Group.3, c("May", "June", "August"))

holo_total <- ggplot(data=test.df12, aes(x=Group.1, y=Abundance, fill=Group.2)) +
  geom_bar(colour="black", size=0.3, stat="identity", width=0.5) +
  facet_grid(~Group.3) +
  labs(x="Habitat category", y=expression(paste("Individuals m"^{-3})), fill="Zooplankton
group") +
  theme_bw() +
  theme(panel.grid.major = element_blank(),
        panel.grid.minor = element_blank(),
        strip.background = element_rect(fill = "gray88", colour = "black"),
        panel.border = element_rect(colour = "black")) +
  theme(plot.title = element_text(size=20, margin=margin(t=20, b=20)),
        legend.text = element_text(size = 25),
        legend.title = element_blank(),
        #legend.position="bottom",
        axis.title.x = element_text(size = 30),
        axis.text.y = element_text(hjust=0.5, size = 24),
        axis.title.y = element_text(size = 30),
        axis.text.x = element_text(hjust=1, size = 22, angle = 45),
        strip.text.x = element_text(size = 25, colour = "black")) +
  scale_fill_brewer(palette="Set3",
                    labels=c("A.","C","C", "C", "E", "M", "O", "O", "O", "P")) +
  scale_colour_manual(palette="Set3") +
  theme(plot.title = element_text(size=20, margin=margin(t=20, b=20)))

holo_total
```

#Trophic mode - Relative abundance

```
test.df10 <- aggregate(trophic,
                       by= list(trophic$Type, trophic$Trophic, trophic$Month),
                       FUN= mean)

test.df10$Group.1 <- factor(test.df10$Group.1, c("Estuary","Inner", "Outer", "Marine"))
test.df10$Group.3 <- factor(test.df10$Group.3, c("May", "June", "August"))

trophic <- ggplot(data=test.df10, aes(x=Group.1, y=Relative_abundance, fill=Group.2)) +
  geom_bar(colour="black", size=0.3, stat="identity", width=0.5) +
```

```
  facet_grid(~Group.3) +
  labs(x="Habitat category", y="Relative abundance") + #fill="Trophic mode"
  theme_bw() +
  theme(panel.grid.major = element_blank(),
        panel.grid.minor = element_blank(),
        strip.background = element_rect(fill = "gray88", colour = "black"),
        panel.border = element_rect(colour = "black")) +
  theme(plot.title = element_text(size=20, margin=margin(t=20, b=20)),
        legend.text = element_text(size = 25),
        legend.title = element_blank(),
        #legend.position="bottom",
        axis.title.x = element_text(size = 30),
        axis.text.y = element_text(hjust=0.5, size = 24),
        axis.title.y = element_text(size = 30),
        axis.text.x = element_text(hjust=1, size = 22, angle = 45),
        strip.text.x = element_text(size = 25, colour = "black")) +
  scale_fill_brewer(palette="Paired",
                    labels=c("H","O","P")) +
  scale_colour_manual(palette="Paired") +
  theme(plot.title = element_text(size=20, margin=margin(t=20, b=20)))

trophic

#Predators - Total abundance

test.df20 <- aggregate(predator,
                       by= list(predator$Type, predator$Taxon, predator$Month),
                       FUN= mean)

test.df20$Group.1 <- factor(test.df20$Group.1, c("Estuary","Inner", "Outer", "Marine"))
test.df20$Group.3 <- factor(test.df20$Group.3, c("May", "June", "August"))

predator_total <- ggplot(data=test.df20, aes(x=Group.1, y=Abundance, fill=Group.2)) +
  geom_bar(colour="black", size=0.3, stat="identity", width=0.5) +
  facet_grid(~Group.3) +
  labs(x="Habitat category", y=expression(paste("Individuals m"^{-3})), fill="Zooplankton
group") +
  theme_bw() +
  theme(panel.grid.major = element_blank(),
        panel.grid.minor = element_blank(),
        strip.background = element_rect(fill = "gray88", colour = "black"),
        panel.border = element_rect(colour = "black")) +
  theme(plot.title = element_text(size=20, margin=margin(t=20, b=20)),
        legend.text = element_text(size = 25),
        legend.title = element_blank(),
        #legend.position="bottom",
        axis.title.x = element_text(size = 30),
        axis.text.y = element_text(hjust=0.5, size = 24),
        axis.title.y = element_text(size = 30),
        axis.text.x = element_text(hjust=1, size = 22, angle = 45),
        strip.text.x = element_text(size = 25, colour = "black")) +
  scale_fill_brewer(palette="Accent",
                    labels=c("A","B","C", "D", "M", "P", "T")) +
  scale_colour_manual(palette="Accent") +
  theme(plot.title = element_text(size=20, margin=margin(t=20, b=20)))

predator_total

#Shannon Wiener Diversity Index:

#Import data#
SW_m3 <- read.csv("Shannon_wiener_m3.csv", sep = ";", header = T)

#Create vectors
Zooplankton <- SW_m3[,3:37]
Station <- SW_m3[,1]

#Shannon-Wiener:
install.packages("vegan")
library(vegan)
diversity(Zooplankton[-1], index="shannon")

#Shannon-Wiener (2):
install.packages("plyr")
library(plyr)
ddply(Zooplankton,~Station,function(x) {
  data.frame(SHANNON=diversity(x[-1], index="shannon"))
```

```
})
```

```
#APPENDIX

#All species - Total abundance - m2

test.df1 <- aggregate(allspecies,
                      by= list(allspecies$Type, allspecies$Species_group, allspecies$Month),
                      FUN= mean)

test.df1$Group.1 <- factor(test.df1$Group.1, c("Estuary", "Inner", "Outer", "Marine"))
test.df1$Group.3 <- factor(test.df1$Group.3, c("May", "June", "August"))

all_species_total_m2 <- ggplot(data=test.df1, aes(x=Group.1, y=Abundance_per_m2,
fill=Group.2)) +
  geom_bar(colour="black", size=0.3, stat="identity", width=0.5) +
  facet_grid(~Group.3) +
  labs(x="Type of station", y=expression(paste("Individuals m"^{-2})), fill="Zooplankton
group") +
  theme_bw() +
  theme(panel.grid.major = element_blank(),
        panel.grid.minor = element_blank(),
        strip.background = element_rect(fill = "gray88", colour = "black"),
        panel.border = element_rect(colour = "black")) +
  theme(plot.title = element_text(size=20, margin=margin(t=20, b=20)),
        legend.text = element_text(size = 25),
        legend.title = element_blank(),
        legend.position="bottom",
        axis.title.x = element_text(size = 30),
        axis.text.y = element_text(hjust=0.5, size = 24),
        axis.title.y = element_text(size = 30),
        axis.text.x = element_text(hjust=1, size = 22, angle = 45),
        strip.text.x = element_text(size = 25, colour = "black")) +
  scale_fill_brewer(palette="Accent",
                    labels=c("Copepoda nauplii","Copepodite stages", "Large copepods",
"Meroplankton", "Other", "Small copepods")) +
  scale_colour_manual(palette="Accent") +
  theme(plot.title = element_text(size=20, margin=margin(t=20, b=20)))

all_species_total_m2
```

Environmental – zooplankton gradients

```
#DCA#

#Importing library:
library(vegan)
library(ggplot2)
library(goeveg)

#Import "species"
dca.species.log<-read.csv("DCA_SPECIES_log.csv",header=T, sep = ";")
attach(dca.species.log)
names(dca.species.log)

#Import "stand"
stand.data.log<-read.table("DCA_STAND.csv",header=T, sep = ";")
attach(stand.data.log)
names(stand.data.log)

#Running DCA on species-plot matrix:
dca.r.log<-decorana(dca.species.log)
summary(dca.r.log)
dca.r.log #DCA1: 31.3% DCA2: 8.9%

#Extracting DCA-axes for plot scores:
dca1.log<-scores(dca.r.log,display="sites",origin=FALSE)[,1]
#Note that origin=FALSE implies that origo of the ordination diagram is moved
#from the centroid to the lower end of each axis
dca2.log<-scores(dca.r.log,display="sites",origin=FALSE)[,2]

#Plotting DCA - with points:
plot(dca1.log,dca2.log,xlab="DCA1",ylab="DCA2",type="n")
```

```
plot(dca1.log,dca2.log,xlab="DCA1",ylab="DCA2",pch=16)

# - with plot numbers:
plot(dca1.log,dca2.log,xlab="DCA1",ylab="DCA2",type="n")
labels<-c(1:47)
text(dca1.log,dca2.log,labels,cex=0.75)

#Extracting DCA-axes for species scores:
dca11.log<-scores(dca.r.log,display="species",origin=TRUE)[,1]
dca22.log<-scores(dca.r.log,display="species",origin=TRUE)[,2]

#Allocating all species names to "label":
labels2.log<-names(dca.species.log)
labels2.log

#Plotting species names:
plot(dca11.log,dca22.log,xlab="DCA1",ylab="DCA2",type="n")
text(dca11.log,dca22.log,cex=0.75,labels2.log)
lines(c(0,0),c(-5,5),col=8,lty=2)
lines(c(-5,5),c(0,0),col=8,lty=2)

#Extracting DCA-axes with origin=T:
dca111.log<-scores(dca.r.log,display="sites",origin=TRUE)[,1]
dca222.log<-scores(dca.r.log,display="sites",origin=TRUE)[,2]

#Loading and attaching environmental variable matrix:
dca.env.log<-read.csv("DCA_ENV.csv",header=T, sep = ";")
attach(dca.env.log)
names(dca.env.log)
str(dca.env.log)

dca.env.surf <- dca.env.log[1:47,c(1,2,4,8,10,12,14)]

## Select the 30% most abundant species and call the result
limitedspecies.log <- ordiselect(dca.species.log, dca.r.log, ablim = 0.3)
limitedspecies.log

#PLOT#

#All environmental factors
dca.log<-
envfit(scores(dca.r.log,display="sites",choices=1:4,origin=TRUE)[,1:2],dca.env.log,999)
plot(dca111.log,dca222.log,xlim=c(-2,2),ylim=c(-1,1), xlab="DCA1(29.8%)",ylab="DCA2(10.0%)",
type="n")
points (dca111.log,dca222.log,cex=2,pch=c(21,22,24)[Month],col=c("black"),
bg=c("lightsalmon4","cornsilk","blue","lightblue3")[Type])
plot(dca.log,arrow.mul=1.2,col=1,add=T,cex=0.75)
lines(c(0,0),c(-5,5),col=8,lty=2)
lines(c(-5,5),c(0,0),col=8,lty=2)
#ordipointlabel(dca.r, scaling = scl,
#display = "species", select = limitedspeciesdca, col = "red", cex=0.7, add=TRUE)

#Only surface factors
dca.log.surface<-
envfit(scores(dca.r.log,display="sites",choices=1:4,origin=TRUE)[,1:2],dca.env.surf,999)
plot(dca111.log,dca222.log,xlim=c(-3,3),ylim=c(-1.5,1.5),xlab="DCA1(31.3%)",ylab="DCA2(8.9%)",
type="n")
points (dca111.log,dca222.log,cex=2,pch=c(21,22,24)[Month],col=c("black"),
bg=c("lightsalmon4","cornsilk","blue","lightblue3")[Type])
plot(dca.log.surface,arrow.mul=1.9,col="grey30",add=T,cex=1.2)
lines(c(0,0),c(-5,5),col=8,lty=2)
lines(c(-5,5),c(0,0),col=8,lty=2)
ordipointlabel(dca.r.log, scaling = scl,
display = "species", select = limitedspecies.log, col = "dodgerblue4", cex=0.85, add=TRUE)
```

#CCA#

```
#Import packages#
library(vegan)
library(na.tools)

#Read file#
ZOO_CCA_m3 <- read.csv("CCA_dataset_m3.csv",header=T, sep = ";")
na.rm(ZOO_CCA_m3)
attach(ZOO_CCA_m3)

#Make species and environmental vectors
```

```
CCA_m3_zoo <-ZOO_CCA_m3[1:47,25:56]
CCA_m3_env <- ZOO_CCA_m3[1:47,7:20]
CCA_m3_station <- ZOO_CCA_m3[1:47,1]
CCA_m3_type <- ZOO_CCA_m3[1:47,2]
CCA_m3_type2 <- ZOO_CCA_m3[1:47,3]
CCA_m3_type3 <- ZOO_CCA_m3[1:47,4]
CCA_m3_fjord <- ZOO_CCA_m3[1:47,5]
CCA_m3_month <- ZOO_CCA_m3[1:47,6]
CCA_m3_depth <- ZOO_CCA_m3[1:47,7]
CCA_m3_temp <- ZOO_CCA_m3[1:47,8]
CCA_m3_temp_15m <- ZOO_CCA_m3[1:47,9]
CCA_m3_salinity <- ZOO_CCA_m3[1:47,10]
CCA_m3_salinity_15m <- ZOO_CCA_m3[1:47,11]
CCA_m3_pH <- ZOO_CCA_m3[1:47,12]
CCA_m3_chla <- ZOO_CCA_m3 [1:47,14]
CCA_m3_chla_15m <- ZOO_CCA_m3 [1:47,15]
CCA_m3_turbidity <- ZOO_CCA_m3[1:47,16]
CCA_m3_turbidity_15 <- ZOO_CCA_m3[1:47,17]
CCA_m3_julien <- ZOO_CCA_m3[1:47,18]
CCA_m3_photic <- ZOO_CCA_m3[1:47,19]
CCA_m3_secchi <- ZOO_CCA_m3[1:47,20]

#Choose the most abundant species (30%)
limitedspecies.cca <- ordiselect(CCA_m3_zoo, CCA_m3, ablim = 0.3)
limitedspecies.cca

#Test the variables for variation explained

CCA_STATION_m3<-cca(CCA_m3_zoo~Station)
CCA_STATION_m3

CCA_MONTH_m3<-cca(CCA_m3_zoo~Month)
CCA_MONTH_m3
anova(CCA_MONTH_m3)

CCA_FJORD_m3<-cca(CCA_m3_zoo~Fjord)
CCA_FJORD_m3
anova(CCA_FJORD_m3)

CCA_TYPE_m3<-cca(CCA_m3_zoo~Type)
CCA_TYPE_m3
anova(CCA_TYPE_m3)

CCA_DEPTH_m3<-cca(CCA_m3_zoo~CCA_m3_depth)
CCA_DEPTH_m3
anova(CCA_DEPTH_m3)

CCA_TEMP_m3<-cca(CCA_m3_zoo~CCA_m3_temp)
CCA_TEMP_m3
anova(CCA_TEMP_m3)

CCA_TEMP_m3_15m<-cca(CCA_m3_zoo~CCA_m3_temp_15m)
CCA_TEMP_m3_15m
anova(CCA_TEMP_m3_15m)

CCA_TURB_m3<-cca(CCA_m3_zoo~CCA_m3_turbidity)
CCA_TURB_m3
anova(CCA_TURB_m3)

CCA_TURB_m3_15m<-cca(CCA_m3_zoo~CCA_m3_turbidity_15)
CCA_TURB_m3_15m
anova(CCA_TURB_m3_15m)

CCA_SECCHI_m3<-cca(CCA_m3_zoo~CCA_m3_secchi)
CCA_SECCHI_m3
anova(CCA_SECCHI_m3)

CCA_SALINITY_m3<-cca(CCA_m3_zoo~CCA_m3_salinity)
CCA_SALINITY_m3
anova(CCA_SALINITY_m3)

CCA_SALINITY_m3_15m<-cca(CCA_m3_zoo~CCA_m3_salinity_15m)
CCA_SALINITY_m3_15m
anova(CCA_SALINITY_m3_15m)

CCA_CHLA_m3<-cca(CCA_m3_zoo~CCA_m3_chla)
CCA_CHLA_m3
```

```
anova.cca(CCA_CHLA_m3)

CCA_CHLA_m3_15m<-cca(CCA_m3_zoo~CCA_m3_chla_15m)
CCA_CHLA_m3_15m
anova(CCA_CHLA_m3_15m)

#Test the variables without including other parameters (such as Julian day and month)

#Surface parameters
CCA_m3_surf<-
cca(CCA_m3_zoo~Temp_surface+Turbidity_surface+Salinity_surface+Chla_GFF_surface+Secchi_depth+C
ondition(Month+Julien_day))
CCA_m3_surf
anova(CCA_m3_surf, by="term")

#PLOT#

#CCA plot showing the constraining variables as vectors - with TYPE in different colours.
plot(CCA_m3_surf,type="n",xlab='CCA 1 (6.4%)',ylab='CCA 2 (2.6%)', xlim=c(-5.5,5),ylim=c(-
2,3))
points (CCA_m3_surf,cex=1.8,pch=c(21,22,24)[CCA_m3_month],
col=c("black","black","black","black")[CCA_m3_type],
bg=c("lightsalmon4","cornsilk","blue","lightblue3")[CCA_m3_type])
#text(Zooplankton.cca,adj=1,col="black",cex=0.7, labels=Station)
text(CCA_m3_surf,display="bp",col="black",arrow.mul = 3.5, cex=1.4)
ordipointlabel(CCA_m3, scaling = "symm",
               display = "species", select = limitedspecies.cca, col = "dodgerblue4", cex=1.02,
add=TRUE)
```