Master's thesis

NTNU
Norwegian University of Science and Technology
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Department of Biology

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Seasonal variations in food-web dynamics of Barents Sea plankton communities in a changing Arctic

Master's thesis in Ocean Resources
Supervisor: Nicole Aberle
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Abstract

The Arctic is currently undergoing sea ice melting at a rapid pace, which could have detrimental impact on the marine Arctic food-webs. Phytoplankton is essential for life in the ocean, and is preyed upon by zooplankton, which acts as a trophic link to higher trophic levels e.g. marine mammals, fish and seabird colonies. Late autumn and winter are poorly studied seasons in the Arctic, and seasonal studies are important to increase our knowledge on future ecosystem changes. This will enhance future ecosystem management strategies and help to protect the Barents Sea ecosystem. Measuring growth and grazing rates of phytoplankton and microzooplankton in the Barents Sea gives an increased understanding of plankton communities. This is important for predicting how future warming can impact the community dynamics. Samples were collected during Nansen Legacy seasonal cruises in March and May 2021 and August and December 2019. Three stations were sampled: P7 that was ice-covered the entire year, P4 that was seasonally ice-covered and P1 which had open water the entire year.

The aim of the thesis was to investigate growth of phytoplankton and microzooplankton, and grazing rates of microzooplankton, for the different seasons and stations sampled. This should enhance data availability, especially on microzooplankton grazing rates that, have been poorly studied in the Arctic so far. Dilution experiments were carried out to uncouple rate estimates of phytoplankton growth and microzooplankton grazing. Additional treatments with the copepods *Calanus* spp. and *Oithona* spp. were set up to look at the potential of top-down control and selective grazing by mesozooplankton. Nutrient treatments were set up to look at the potential of nutrient limitation.

The results showed that there were seasonal differences in phytoplankton abundances with higher abundance in spring compared to winter, and that microzooplankton abundances followed the increase in phytoplankton abundance. There was a shift in the community composition from dominance of Cryptophyta to flagellates and diatoms from March to May, with the most abundant diatoms being *Thalassiosira* spp. and *Chaetoceros* spp. Across all seasons the most abundant microzooplankton was the athecate dinoflagellate *Gymnodinium* spp. The highest growth rates for phytoplankton were found in May, due to pre-bloom conditions, and the highest growth rates of microzooplankton in August. Microzooplankton grazing rates remained relatively constant across all seasons, probably due to internal predation. No nutrient limitation was found for any of the seasons or stations. The higher growth rates in spring indicated a bottom-up controlled plankton community early in the season. The following decrease in phytoplankton abundance in August and increase in microzooplankton growth rates, indicated a top-down controlled plankton community later in August.

Sammendrag

Havisen i Arktis gjennomgår for tiden smelting i et raskt tempo, noe som kan ha store innvirkning på marine arktiske næringsnett. Planteplankton er essensielt for livet i havet, og er en viktig matkilde for dyreplankton, som fungerer som en trofisk kobling til høyere trofiske nivåer, f.eks marine pattedyr, fisk og sjøfuglkolonier. Senhøst og vinter er lite studerte årstider i Arktis, og sesongstudier er viktige for å øke vår kunnskap om fremtidens endringer økosystemer. Dette for å forsterke fremtidige forvaltnings strategier og for å hjelpe å beskytte økosystemet i Barentshavet. Måling av vekst og beiterater av planteplankton og dyreplankton i Barentshavet gir økt forståelse for planktonsamfunnene. Dette er viktig for å kunne forutsi hvordan fremtidig oppvarming kan påvirke samfunnsdynamikken. Det ble samlet inn prøver på sesongtoktene til Arven etter Nansen i mars og mai 2021 og august og desember 2019. Det ble tatt prøver fra tre stasjoner: P7 som var isdekket hele året, P4 som var sesongmessig isdekket og P1 som hadde åpent vann hele året.

Målet med oppgaven var å undersøke vekst av planteplankton og dyreplankton, og beiterater for dyreplankton, for de ulike årstidene og stasjonene som ble tatt prøver av. For å gi mer vitenskapelige data om spesielt beitehastigheter til dyreplankton, som er lite studert i Arktis. Fortynningseksperiment ble utført for å koble fra rateestimater for planteplankton vekst og dyreplankton beiting. Ytterligere behandlinger med hoppekrepsene *Calanus* spp., og *Oithona* spp. ble satt opp for å se på potensialet for toppstyrt kontroll og selektiv beiting. Næringsbehandling ble satt opp for å se på potensialet for næringsbegrensning.

Resultatene viste at det var sesongmessige forskjeller i abundans av planteplankton med høyere abundans om våren sammenlignet med vinteren, og at abundans av dyreplankton var høyere senere på sommeren. Det var et skifte i samfunnssammensetningen i dominansen av Cryptophyta til flagellates og kiselalger fra mars til mai, med de mest tallrike kiselalgene *Thalassiosira* spp. og *Chaetoceros* spp. På tvers av alle årstider var det mest tallrike mikrozooplanktonet atekat dinoflagellaten *Gymnodinium* spp. De høyeste vekstratene for planteplankton ble funnet i mai, på grunn av gunstige vekstforhold, med de høyeste vekstratene for dyreplankton i august. Beitehastigheten for dyreplankton var ikke forskjellig på tvers av årstidene, noe som indikerer intern predasjon. Ingen næringsstoffbegrensninger ble funnet for noen av årstidene eller stasjonene. De høyere vekstratene om våren indikerte på et nedenfra og opp kontrollert planktonsamfunn tidlig på sesongen. Følgende nedgang i planteplankton abundans i august og økning i dyreplankton vekst, indikerte et ovenfra-og-ned kontrollert planktonsamfunn senere i august.

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Maria Ivarsdatter Rosland

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List of abbreviations

ArW	Arctic Water
AW	Atlantic Water
BSW	Barents Sea Water
PFW	Polar Front Water
MW	Melt water
BW	Bottom Water
SW	Seawater
Chl *a*	Chlorophyll *a*
FFT	Funnel transfer technique
DF	Dinoflagellate
Q1	March
Q2	May
Q3	August
Q4	December

1. Introduction

1.1 The Arctic

The Arctic is known for its extreme cold and unfavourable weather, which makes it one of the most inaccessible areas on Earth (Comiso & Parkinson, 2004). It consists of an ocean encircled by land, and this ocean is called the Arctic Ocean. The Arctic Ocean and its adjacent shelf seas (including the Barents Sea) cover an area of 14 million km^2 (Barry, 1989). Over 50% of the Arctic Ocean consists of shallow continental shelves, and these play an important role in transforming the water masses that eventually return to the global circulation (Carmack et al., 2006). In March (late winter) the Arctic Ocean is almost entirely covered in sea ice up to 2-3 m thick, and during August/September (summer) the sea ice extent is at its minimum (Comiso & Parkinson, 2004; Przybylak et al., 2003).

The marine ecosystem in the Arctic is unique and consists of diverse habitats, this is due to the extreme seasonality in climate between seasons. In regards to sea ice-cover, light availability and temperatures (Riedel, 2013). The base of Arctic marine food-webs consist of phytoplankton that convert inorganic matter to organic matter, through photosynthesis. This organic matter is then consumed by zooplankton, which in turn are eaten by other marine organisms, such as fish, sea birds and baleen whales (Loeng et al., 2005). Thus creating a food-web with each organism constituting a trophic level, where phytoplankton is the first trophic level. Sea ice is a habitat for many species, so called sympagic organisms that live in or close to the sea ice, such as amphipods and polar cod (Loeng et al., 2005). The sea ice is also an important habitat and feeding habitat for polar bears, that hunt ringed seals (Stirling & Derocher, 1993). Melting of sea ice in the summer is an important event, as the sympagic communities provide the pelagic (free floating) and benthic (sea floor) communities with food (Loeng et al., 2005).

1.2 The Barents Sea and its hydrography

The Barents Sea is a semi-enclosed sea which is surrounded to the south by the northern coast of Europe, to the east by Novaya Zemlya and to the west by the Norwegian Sea. The shelf break passing north of Svalbard and Franz Josef Land is the northern border of the Barents Sea. It is a part of the shelf seas that form the Arctic Continental Shelf and is one of the most productive polar shelf ecosystems (Franzè & Lavrentyev, 2017). The Barents Sea is a marginal sea that has a combination of large distances from the shores and relatively shallow water depths, with an average depth of 230 m. It has high latitude light conditions, with longer periods of 24h daylight and 24h darkness (Connan-McGinty et al., 2022), and receives circulation of heat, salt, nutrients, and biomass from the Norwegian Atlantic Current (Rat'kova & Wassmann, 2002).

The Barents Sea is an inflow shelf that has inflow of Coastal Water (CW) from the south, Atlantic Water (AW) from the south and Arctic Water (ArW) from the north (Carmack et al., 2006; Loeng, 1991) (Figure 1). The main currents entering the Barents Sea are The Norwegian Coastal Current which brings Coastal Water and The Norwegian Atlantic Current which brings Atlantic water. From the North Arctic water enters the Barents Sea from the Arctic Ocean, by the Persey and east Spitsbergen Currents (Harris et al., 1998; Loeng, 1991). In the southern Barents Sea, the currents are directed toward the east, while in the north they are directed to the West or South-West (Loeng, 1991).

Shelf-sea ecosystems are high productive ecosystems, and the Barents Sea supports a large stock of marine mammals, large seabird colonies and it contains a big and important fishery for Norway and Russia (Wassmann et al., 2006). This is due to the high biomass of phytoplankton and zooplankton, that supports large stocks of fish, such as capelin that is regarded as a key species in Arctic food-webs. Capelin feeds mainly on zooplankton such as copepods, strengthening the importance of phytoplankton and zooplankton in Arctic marine ecosystems (Hamre, 1994; Sakshaug, 1997).

The polar front is an oceanographic feature in the eastern Barents Sea, where AW meets ArW (Figure 1). Resulting in the mixing of Atlantic water with Arctic water that creates a water mass boundary that is important for water mass modification (Arashkevich et al., 2002; Barton et al., 2018; Harris et al., 1998). The location of the polar front can be influenced by the position of the ice edge, surface temperatures and surface salinity as it affects the polar front's surface density gradient. The polar front can be looked at as a shift between the more salinity-stratified northern Barents Sea and more temperature-stratified southern Barents Sea. Since 2005 the polar front has intensified, leading to a barrier that blocks the formation and export of sea ice south of the polar front (Barton et al., 2018). Due to inflow of AW from the south, the temperature in the southwestern Barents Sea is warmer than the rest of the Barents Sea, with the sea surface temperatures usually between 4°C in spring to 8°C in summer. With the polar front as a barrier, the northern Barents Sea experiences lower sea surface temperatures from -1.8°C in spring to 2°C in summer (Barton et al., 2018).

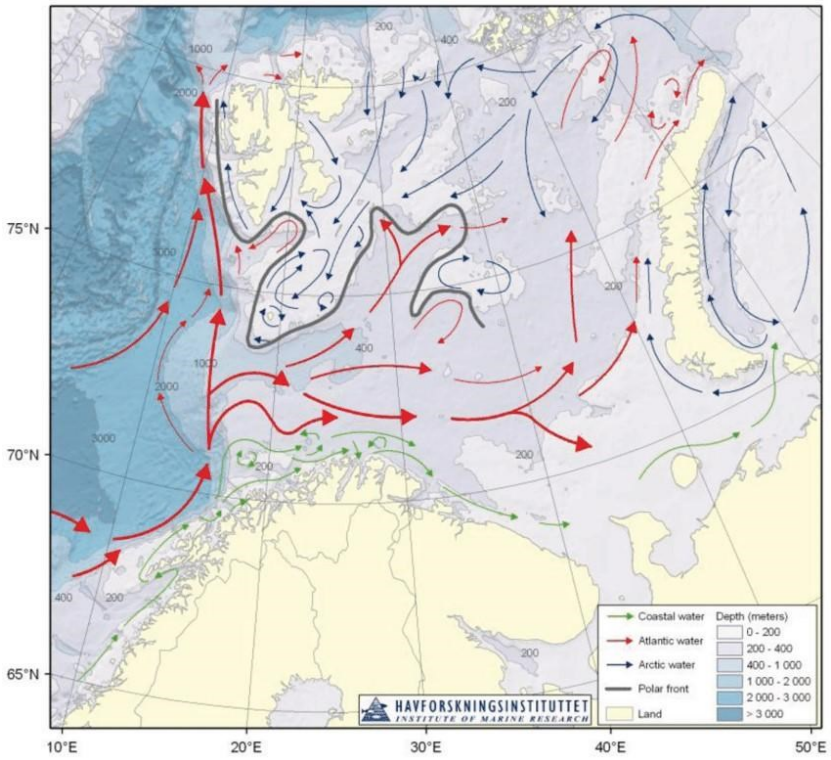


Figure 1: Map of the bathymetry in the Barents Sea showing the currents. Green is Coastal Water (CW) from the Norwegian Coastal Current. Red is Atlantic Water (AW) from The Norwegian Atlantic Current and blue is Arctic Water (ArW) from the Persey and east Spitsbergen Currents. Grey line is the polar front. Figure with permission from Stiansen et al. (2009), made by The Institute of Marine Research (IMR).

1.3 Sea ice and snow cover

Winter conditions in the Barents Sea are characterized by an extensive ice-cover, that can cover up to 90% of the sea surface, low irradiance, and deep mixing of the water columns. Due to these conditions in winter, the phytoplankton biomass is sparse in Arctic seas (e.g. Franzè and Lavrentyev, 2017; Rat'kova and Wassmann, 2002). However, due to inflow of warmer and more saline Atlantic water it is the only Arctic region that remains ice-free throughout the entire year below 74-75°N (Carmack et al., 2006; Franzè & Lavrentyev, 2017; Rat'kova & Wassmann, 2002). Due to increasing seawater temperatures the Barents Sea is undergoing atlantification, which can lead to increased demand for nutrients and northward expansion of invasive marine species (Barton et al., 2018; Polyakov et al., 2020).

The sea ice in the Barents Sea grows from fall through winter, with the peak in ice extent in March/April. The sea ice concentration then declines through spring and summer as the melting season happens, with a sea ice minimum in September (Vinje & Kvambekk, 1991). The sea ice has shown strong seasonality, by retreating to the northern parts of the Barents Sea in summer and advancing southeast to the Central Bank in winter. It also varies in extent and duration every year due to the seasonal cycle (Barton et al., 2018; Carmack et al., 2006; Wassmann & Reigstad, 2011). The sea ice is constantly in motion due to wind, tide and ocean currents, and this dynamic creates open-water areas such as leads and polynyas. Through these open-water areas the ocean loses heat due to the air temperatures being much lower than the sea-surface temperatures (Przybylak et al., 2003). Snow cover on top of the sea ice also plays an important role in climate, as the snow is highly reflective, has high infrared emission and high insulating properties. A snow cover that is more than 15 cm thick can completely stop the heat transport between atmosphere and sea ice (Przybylak et al., 2003).

A study done from 1979 to 2006 found that the Barents Sea sea ice extent in spring is significantly decreasing at a rapid pace (Parkinson & Cavalieri, 2008). Decrease in the sea ice cover leads to increased solar heat into the ocean, which can cause further thinning of sea ice and reduce the sea ice cover more (Perovich et al., 2007). Sea ice dynamics are important for the production in the Arctic, not only as a habitat for the Arctic mammals, fish and sympagic fauna that depend on it. Earlier ice melt, and more open water areas can disrupt the timing and magnitude of the spring bloom of phytoplankton (Loeng et al., 2005).

1.3.1 Seasonality of light

The Barents Sea ecosystem is not only influenced by the seasonality of the sea ice-cover, but also by the seasonality of light (Connan-McGinty et al., 2022). Light in the Arctic is influenced by the seasonal changes in solar radiation, which causes Polar Days (24h daylight) and Polar Nights (24h darkness). This seasonality in light intensity leads to substantial differences in the magnitude and spectral composition of the light that enters the ocean (Connan-McGinty et al., 2022). However, Polar Nights are not completely dark, as the moon becomes the dominant source of irradiance in the darkest winter periods (Johnsen et al., 2021). Light is also an important environmental cue for zooplankton as they match their vertical migration to the surface for feeding by light intensities (Hobbs et al., 2021). In the winter the daily migration is regulated by the phase and altitude of the moon, maintaining the predator-prey interactions (Last et al., 2016; Søreide et al., 2010).

1.4 Phytoplankton-zooplankton interactions

1.4.1 Phytoplankton

In addition to light phytoplankton needs sufficient nutrients to perform photosynthesis, which is essential for their growth (Harrison & Cota, 1991). Phytoplankton are the main producers of organic matter in the ocean. Since the North Barents Sea is seasonally ice-covered, production by phytoplankton happens both in open water and under the sea ice (Hegseth, 1998). In late spring and summer ice-algae provide additional production, and are responsible for 16-25% of the total primary production in the Barents Sea (Carmack et al., 2006; Hegseth, 1998).

In terms of phytoplankton diversity, the lowest number of species has been found in March and the highest number of species in June/July in the Barents Sea (Rat'kova & Wassmann, 2002). *Chaetoceros* spp., and *Thalassiosira* spp. (both diatoms), and *Gyrodinium* spp. and *Protoperidinium* spp. (both dinoflagellates) have been found to be very abundant in summer, but less abundant in spring. In June/July dinoflagellate species have been found to be more abundant (Rat'kova & Wassmann, 2002).

In temperate and polar seas, phytoplankton have periods of large biomass increase in the spring called blooms, that are an important source of food for zooplankton. These blooms takes place due to increased sunlight and stabilized wastermasses that allow for increased nutrient uptake (Silva et al., 2021). In ice-covered waters, in the North Barents Sea, the spring bloom tends to happen after the sea ice break-up, when the water column gets stratified (Carmack et al., 2006; Søreide et al., 2010). Ice-algae usually blooms earlier than pelagic phytoplankton, and are an important early food source for grazers such as copepods (Leu et al., 2015). In summer these algae are sparse. This can be explained by nutrient depletion, leading to an inhibition of algae growth, in addition to meltwater input leading to a physical disturbance that releases the algae from the ice (Rat'kova & Wassmann, 2002).

1.4.2 Zooplankton

Microzooplankton are a component of zooplankton consisting of protozoans, such as ciliates and dinoflagellates, and metazoans, such as copepod nauplii, within the size range of 20-200 µm. They form a trophic link between nanophytoplankton and mesozooplankton (Gifford, 1985; Landry & Hassett, 1982). Microzooplankton are key components in marine food webs as they are top predators in microbial food webs and they graze more than mesozooplankton (Calbet, 2008; Calbet & Saiz, 2005; Sherr & Sherr, 2009). Grazing by microzooplankton is essential since it suppresses the pelagic primary production considerably and leads to a recycling of matter and energy within the microbial loop (Franzè & Lavrentyev, 2017; Calbet. Albert, 2008; Sherr & Sherr, 2009).

Microzooplankton, especially heterotrophic dinoflagellates, can also feed on rather large prey items e.g. large diatoms (Sherr & Sherr 2009), which dominate the marginal ice zone. Microzooplankton herbivory is a key factor in both diatom- and flagellate-dominated waters of the Barents Sea, and a leading top-down control on phytoplankton growth in polar waters (Franzè & Lavrentyev, 2017). Microzooplankton are also important in the pelagic food webs, since they show high specific growth rates, metabolism and feeding. Generally, they are considered to feed on small-sized particles that remain unutilized by larger consumers, thereby they can be viewed as trophic

intermediates. Phytoplankton composition is directly linked to microzooplankton composition due to their selective feeding habits and distinct feeding preferences (Landry & Hassett, 1982).

The southern Barents Sea experiences large-scale advection of Atlantic zooplankton. Open Barents Sea waters are mainly dominated by nanophytoplankton, thus leading large copepods to rely more on microzooplankton as prey with substantial cascading effects on the microbial food web (Franzè & Lavrentyev, 2017). Any shifts in surface productivity can have effects on the pelagic-benthic coupling, food-web structure, and CO2 uptake (Brown & Arrigo, 2012). However, it has been shown that there are seasonal, interannual and regional fluctuations in the abundance and structure of the zooplankton community. The seasonal fluctuations can be explained by the strong seasonal pulse in the environmental conditions, often found in high-latitude ecosystems (Arashkevich et al., 2002).

The mesozooplankton abundance varies seasonally and tends to follow the same trend as primary production with a lag period of about a month (Skjoldal et al., 1987). Calanoid copepods which are important consumers graze around 20% of primary production in spring and between 65-90% in summer (Rat'kova & Wassmann, 2002). Copepods such as *Calanus finmarchicus* and *Calanus glacialis* are key mesozooplankton species in the Barents Sea, as they can contribute to up to 90% of the total zooplankton biomass in the summer period (Arashkevich et al., 2002). *Calanus glacialis* is a true Arctic species and is important for Arctic marine food-webs. It grazes phytoplankton and ice algae and is preyed upon by Arctic fish, seabirds and other predators. This copepod forms a link between primary producers and higher trophic levels, which is important for the energy transfer up the food web (Cleary et al., 2017). *Calanus finmarchicus* has been found to dominate the mesozooplankton biomass in the Barents Sea and is an important part of the diet for fish stocks. It is hypothesized that *Calanus finmarchicus* is advected from the Norwegian Sea into the Barents Sea (Kvile et al., 2017). Abundance of *C. glacialis* and *C. finmarchicus* in the spring has been low, with a peak in abundance in summer and autumn (Hatlebakk et al., 2022).

1.5 Climate-change impacts on the Barents Sea ecosystem

The Arctic is important for Earth's climate, as they contribute to deepwater formation, which impacts the global ocean circulation (Loeng et al., 2005). The species inhabiting the Arcitc are highly specialized and sensitive to climate change, which makes further studies of the Arcitc so important (Loeng et al., 2005; Comiso & Parkinson, 2004). Earlier melting of sea ice can lead to a mismatch in the timing of the phytoplankton spring bloom and feeding of mesozooplankton, that have adapted their spawning to the timing of the blooms (Søreide et al., 2010).

Heterotrophic plankton is believed to be affected by climate change and ocean warming more strongly than autotrophic protists (Rose & Caron, 2007). However, Arctic protists also show broad thermal tolerances (Franzè & Lavrentyev, 2017). Changes at the base of the food web can lead to cascading effects higher up in the food web, such as for herbivorous and omnivorous zooplankton e.g. *Calanus glacialis* that are dependent on autotrophic production from seasonal pulses of phytoplankton and ice algae (Cleary et al., 2017). Phytoplankton and zooplankton dynamics can be controlled either through bottom-up or top-down control. Bottom-up is when the growth of phytoplankton is

controlled by light conditions and the magnitude of nutrients. Top-down is when the growth of phytoplankton is controlled by grazers (Carmack et al., 2006). Having knowledge about growth rates for plankton species and groups is important to understand food-web dynamics and their responses to climate change (Franzè & Lavrentyev, 2014).

The rising temperatures and CO_2 concentrations are predicted to lead to increased warming, freshening and ocean acidification in the coming years (Gerland et al., 2023). Studies have also predicted that there will be a reduction in the sea ice extent in the Arctic, with a seasonally ice-free Arctic Ocean by 2050 (Comiso & Parkinson, 2004). Because the Barents Sea is tightly connected to the dynamics of the sea ice edge, it is likely to have rapid responses to climate change (Carmack et al., 2006). How the primary production in the Barents Sea will react to ongoing changes; if it will increase or decrease is still being debated (Coupel et al., 2015).It is also hypothesized that with more open water due to ice melting there will be increased human activity such as using the Arctic for shipping routes and oil and gas extraction, which will impact the marine ecosystem even further (Wassmann & Reigstad, 2011).

1.6 State of knowledge in the Arctic

Late autumn, winter and early spring are the least investigated seasons in polar waters. This is mainly due to logistical and technical challenges related to sampling campaigns during these seasons e.g. the need of research vessels with high ice-breaking capacity. Sampling in the winter either inshore or in the open sea can be rather difficult (Menden-Deuer et al., 2018). Due to the knowledge-gaps in seasonal studies in the Arctic, full-year sampling campaigns such as the Nansen Legacy seasonal cruises, are important to build a knowledge base for future adaptive and sustainable management. By doing a full-year sampling campaign, the Nansen Legacy created framework for strenghtened scientific databases and gave an outlook for the expected climate state in the future (Reigstad et al., 2019).

Detailed analysis of the seasonal dynamics of plankton in the Barents Sea throughout the entire year can thus enhance our knowledge on the structure and functioning of Arctic coastal ecosystem and their productivity. Plankton in the Arctic is poorly studied (Izarbalz et al., 2023), especially phytoplankton composition in the ice-covered northern part of the Barents Sea (Rat'kova & Wassmann, 2002), and more information and data gathered is important for future assessments.

1.7 Aim of the project

This thesis is a part of the Nansen Legacy Project, a bigger Arctic research project, with the aim of improving the scientific database about the changing Barents Sea ecosystems. The Nansen Legacy Project was funded by the Research Council of Norway and took place from 2018-2023. This thesis was a part of The Living Barents Sea (RF3), which focuses on biodiversity, ecosystem functioning and environmental forcing.

The hypotheses were:

H1: Higher phytoplankton abundance will be found in late spring, when phytoplankton are blooming, which stimulates micro-and mesozooplankton abundances in response to increasing food supply.

H2: Stations P4 and P7 reach spring bloom conditions earlier than P1, due to melting of sea ice and more stratified water columns. This was expected to lead to higher abundance and less diversity than for P1, due to pre-bloom conditions.

H3: Mesozooplankton such as copepods graze on phytoplankton, but also on microzooplankton such as heterotrophic protists. This will be especially the case during times when phytoplankton is low (e.g. during late summer or winter period).

H4: Microzooplankton graze mainly on phytoplankton, but microzooplankton is expected to be abundant also during winter, thus relying on internal predation.

To answer these hypotheses the aim is to:

1) Estimate the growth and grazing rates of different plankton groups along a geographical gradient in the Barents Sea. Investigating three distinct areas, with open water, seasonally ice-covered and ice-covered all year.
2) Investigate seasonal differences in poorly studied seasons (winter, early spring) in the Arctic, thereby increasing the scientific knowledge about seasonal dynamics throughout the entire year.
3) Provide grazing data, which increases the knowledge about micro-and mesozooplankton interactions. Since there is not much data available on microzooplankton grazing in the Arctic.

2. Materials and methods

2.1 Study site

The Barents Sea is a marginal sea that is part of the shelf seas that form the Arctic Continental Shelf. It is a productive polar ecosystem that has large distances from the shores and relatively shallow water depths (Franzè & Lavrentyev, 2017; Rat'kova & Wassmann, 2002). The Barents Sea has an average depth of 230 m, with the deepest parts being around 500 m. During the winter, the surface waters can be 90% covered in sea ice, with the maximum ice cover in February-March. The Barents Sea is the only Arcitc region to remain partially ice-free the entire year, with the sea ice boundary in some years reaching down to 75°N. This is due to inflow of warmer Atlantic Water from the south. (Franzè & Lavrentyev, 2017; Rat'kova & Wassmann, 2002; Smolyar and Adrov, 2003).

2.2 Seasonal Cruises

Samples were collected from three stations: P1, P4 and P7 in The Barents Sea (Figure 2). The Nansen Legacy seasonal cruises Q1 (March), Q2 (May), Q3 (August) and Q4 (December) were all a part of a seasonal investigation of the northern Barents Sea and the adjacent Arctic Basin. This investigation was within the framework of Nansen Legacy Project (funded by NFR) and samplings conducted in 2019 and 2021. The research objective was separated into three packages: "Physical drivers", "Human impact" and "The Living Barents Sea" (Reigstad et al., 2019). The research vessel Kronprins Haakon was used on all the cruises. A total of seven stations (P1-P7) were sampled during the cruises, however, additional growth and grazing experiments were only conducted at stations P1, P4, and P7. Each station was sampled for more than 24 hours to account for a full-day cycle (Gerland et al., 2022; Ludvigsen et al., 2022; Reigstad et al., 2022; Søreide et al., 2022). The focus of the grazing experiment was on the primary producer-consumer link (Ludvigsen et al., 2022).

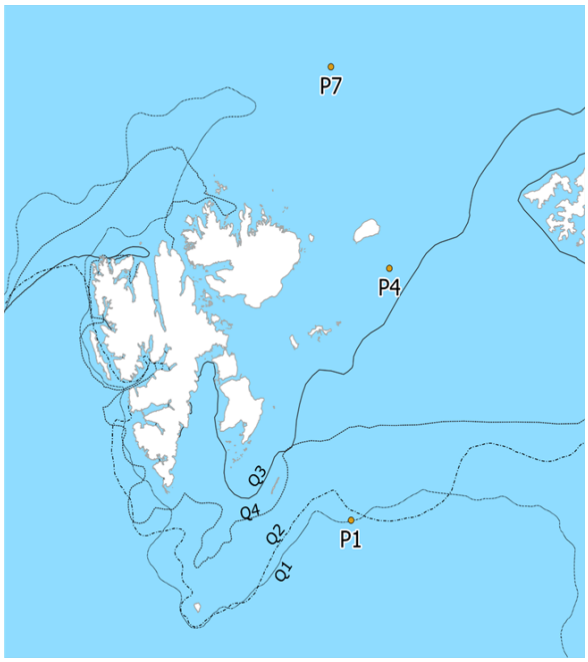


Figure 2: Location of sampling stations and cruise names. Figure credit: Maja Hatlebakk

2.2.1 March (Q1)

Q1 was conducted from 4th (P1) -21st (P7) of March 2021, the cruise was supposed to be conducted in 2020, but due to Covid-related restrictions on all sea-going research it was delayed. It was the 1st quarter of the year cruise in the seasonal series and focused on comparing physical, chemical, and biological conditions, with special focus on sea ice work. This cruise covered the time when it was expected to be the lowest temperatures in the areas sampled and sea ice formation was still ongoing (Gerland et al., 2022).

2.2.1.1 Ice conditions

P4 had 50-60 cm thick first year drift ice, with only minor ridges (around 10% ice ridge concentration) and the ice concentration was close to 10/10 on the sea ice concentration scale by World Meterological Organization (WMO) ((WMO). 2014). The snow thickness was 15-20 cm. At P7, there was recently formed ice in early stages, young grey ice, and young grey ice turning into white ice, but also an ice floe aggregate. This aggregate was composed of three major ice types: 40-50cm thick level ice, 50-70 cm thick level ice and heavily ridged ice rubble areas. This indicates cold and stable temperatures prior to sampling. Snow thickness at P7 was 4-20 cm (Gerland et al., 2022).

For this cruise, sampling included microbial community composition, abundance and activity, phytoplankton abundance and community composition, Chl *a*, and live protist samples (processed on ship). At stations P4 and P7 additional grazing experiments were conducted on board. Chlorophyll *a* maximum (Chl *a* max) was detected (Gerland et al., 2022).

2.2.2 May (Q2)

Q2 was the spring cruise conducted from April 29th (P1) to May 16th (P7) 2021. This cruise was as Q1 delayed due to Covid restrictions. For this cruise P1 was the only open water station. Upon arrival at station P7 there was no phytoplankton bloom conditions. However, after three days of sampling at P7 Chl *a* measurements indicated a subducted decaying bloom at the pycnocline at around 95 m depth (Ludvigsen et al., 2022).

2.2.2.1 Ice conditions

Between stations P3 and P4, ice up to 1.5 m was observed, however, upon arrival at station P4, the ice was thinner (10 cm to 30 cm). The ice observed was covered by ice algae. The ice at P7 was very close drift ice that was over 1 m thick (Cryo.met.no., 2023; Ludvigsen et al., 2022).

2.2.3 Q3

Q3 was conducted from 5th (P1) to 27th (P7) of August 2019. This time, station P1 was located in the open water with Atlantic water flowing in and P4 was sampled as an open water station (Reigstad et al., 2022).

2.2.3.1 Ice conditions

Sea ice charts shows that the sea ice in the Barents Sea had started to melt prior to this cruise, as the sea ice had gone from mostly very close drift ice in the middle of the Barents Sea (close to station P4) to close and open drift ice (Cryo.met.no., 2023). At station P7 the ice thickness varied between 130 and 160 cm (Reigstad et al., 2022).

2.2.4 Q4

Q4 was conducted from 28th of November (P7) to 17th of December 2019 (P1). For the Q4 transect all stations except P1 was covered in a ~1 m thick sea ice layer. This cruise started sampling at P7, and ended at P1, in contrast to the other cruises that started at P1 and ended at P7, this was done to save time (Søreide et al., 2022).

2.2.4.1 Ice conditions

At station P7 the ice thickness varied between 95 and 120 cm (Søreide et al., 2022). Ice charts show that during the time of the cruise the area south of Station P4 had started developing very close drift ice (Cryo.met.no., 2023).

2.3 Stations

Stations P1, P4 and P7 (Figure 2) were sampled for every cruise. P1 was the southernmost open water station with Atlantic influence, P4 was ice-covered during winter, and had thin (10-30 cm) ice or open drift ice in summer. P7 was an ice station with very fast drift ice the entire year (Table 1).

Table 1: Coordinates, maximum depth, Chl *a* max, and depth of thermocline for all three stations P1, P4 and P7 that was sampled for the growth and grazing experiment (Vader et al., 2022a, 2022b, 2022c)

Station	**Coordinates**	**Date sampled**	**Depth [m]**	**Chl *a* max [µg/L]**	**Thermocline [m]**
P1	76.0001°N 31.2201°E	30.04.2021 (Q2)	~326	0.01 (10 m, Q1)	Mixed water column at Q2 and Q4.
		13.12.2019 (Q4)		0.85 (20 m, Q2)	
				1.22 (55 m, Q3)	
				0.04 (200 m, Q4)	
P4	79.770873°N 33.662819°E	10.03.2021 (Q1)	~332	0.01 (90 m, Q1)	~ 70 (Q1)
		05.05.2021 (Q2)		1.2 (20 m, Q2)	~100 (Q2)
		14.08.2019 (Q3)		1.37 (30 m, Q3)	~35 (Q3)
		08.12.2019 (Q4)		0.02 (121 m, Q4)	~80 (Q4)
P7	81.996928°N 29.986175°E	17.03.2021 (Q1)	~3000	0.02 (10 m, Q1)	No thermocline (Q1)
		12.05.2021 (Q2)		0.49 (20 m, Q2)	~90 (Q2)
		21.08.2019 (Q3)		1.74 (10 m, Q3)	~35 (Q3)
		01.12.2019 (Q4)		0.04 (20 m, Q4)	~35 (Q4)

2.4 Sampling

CTD (Conductivity, temperature and depth) was taken from every station and cruise (Table 2) and used to look at water masses (Gerland, 2022a, 2022b, 2022c; Ludvigsen, 2022a, 2022b, 2022c; Reigstad, 2022a, 2022b, 2022c; Søreide, 2022a, 2022b, 2022c).

Table 2: Date of the deployment of CTD (Conductivity, temperature and depth) from the Nansen Legacy seasonal cruises in March (Q1), May (Q1), August (Q3) and December (Q4). For stations P1, P4 and P7.

Station	March (Q1)	May (Q2)	August (Q3)	December (Q4)
P1	X	30.04.2021	X	14.12.2019
P4	11.03.2021	04.05.2021	14.08.2019	08.12.2019
P7	18.03.2021	16.05.2021	21.08.2019	03.12.2019

At each station seawater (SW) was collected at 20 m depth and Bongo nets (HydroBios, 64 µm, opening: 2 x 0.2827 m^2) were hauled from 70-0 m. Samples were taken for phytoplankton and microzooplankton taxonomy and abundance, flow cytometry, nutrients, ammonium, HPLC, Chl *a*, POC/PON and POP before the growth and grazing experiment was set up.

Water samples were collected and handled gently to avoid splashing and shaking that could have damaged the plankton. At each station around 62 L of seawater was collected; 3 L x 18 bottles, with water for filtration, preparation of diluted samples and pre-rinsing of bottles and 8 L for start samples. Seawater was collected with Niskin bottles on a CTD rosette that was emptied through the nozzle with a hose attached. Using the funnel transfer technique (FTT) the water from the Niskin bottles was sieved through a 180 µm sieve to remove mesozooplankton and then into a 20 L barrel. The FTT allows for gentle transfer of water samples without damaging plankton and avoids air bubbles that could harm the plankton (Löder et al., 2010). The barrel was then stored in a room with no light and *insitu* temperatures until the experiment was started.

At Q4, copepods at P1 were collected with a Multinet (HydroBios, 64 µm, opening: 0.25 m^2) through the moonpool of RV Kronprins Haakon from 300-0 m due to rough weather conditions. At P4 and P7 copepods were collected with a Bongo net (64 µm) from 100-0 m. All copepods sampled were pooled, due to low catch densities (Søreide et al., 2022).

At every cruise and station, there was a plastic bag inserted into the cod end of the plankton net used. This was done to protect the plankton in the cod end when the net was being hauled through the water column, as it stops the flow through the cod end and makes the water drain through the net above the cod end. Which created calmer water within the cod end and avoids damage done to the zooplankton. The samples were preserved in cold rooms with *insitu* temperatures and light levels. Individuals used in the experiment were handpicked with a plastic pipette using a Leica binocular and stored in Falcon tubes with filtered SW. Samples were also taken for phytoplankton and microzooplankton taxonomy and abundance, flow cytometry, nutrients, ammonium, HPLC, Chl *a*, POC/PON and POP before the growth and grazing experiment was set up (Gerland et al., 2022).

2.5 Experimental setup

The grazing experiments were based on the dilution technique (Landry & Hassett, 1982). This technique allows estimates on the growth rates of phytoplankton and the grazing impact of microzooplankton (Landry et al., 1995). The dilution technique involves the incubation of water samples with natural plankton communities that are diluted to different degrees using particle free water, where each sample gives an independent estimate of phytoplankton growth measured from bulk chlorophyll, taxa-specific pigments or population counts. For this thesis the abundance (individuals/mL) and Chl *a* were used to calculate growth and grazing rates.

It is assumed that phytoplankton growth rate (μ) is independent of the dilution effect on population density and that the rate of phytoplankton mortality (m) due to grazing by microzooplankton is proportional to the dilution effect on grazer abundance (Landry et al., 1995).

The experiment was set up with a total of 18 bottles, with triplicates of five different treatments: 20% dilution, 100% seawater (SW), 100% SW with *Oithona* spp., 100% SW *Calanus* spp. and 100% SW with added nutrients (1 mL/L) (Figure 3). For the treatments with added *Calanus* spp., 50-102 *Calanus* spp. was added to each bottle, and for *Oithona* spp. it was 4-5 individuals of Oithona spp. (Table 3).

Figure 3: Experimental setup of the grazing experiments with 18 bottles of 2.5 L each, with three replicates of every treatment; 20% dilution, 100% sea water (SW), 100% SW with 50-102 *Oithona* spp., 100% SW with 4-5 *Calanus* spp. and 100% SW with added nutrients (f2 medium, 1 mL/L) See Table 3 for exact number of *Oithona* spp. and *Calanus* spp. added for each station and cruise.

The experiment was prepared in 2.5 L Nalgene bottles and incubated for 43-69 hours (Table 3), at *insitu* temperatures and 24h light regime in May and August. In March, *insitu* light conditions were used and in December no light was applied to parallel the Polar Night conditions.

Table 3: Overview of number of *Oithona* spp., and *Calanus* spp. added to the three replicates of the bottles, temperature for the incubation, incubation duration and amount of nutrients added as f2 medium into each bottle for all cruises and stations. *Calanus glacialis* was used for Q3 and *Calanus finmarchicus* was used for Q4. For Q3 not enough f2 medium was brought onto the cruise, so less than 1 mL was added to each bottle.

		Q1	**Q2**	**Q3**	**Q4**
P1	*Oithona* spp.	X		X	50, 51, 52
	Calanus spp.	X		X	4, 4, 4
	Temperature (°C)	X	2.0	X	-0.5
	Duration (h)	X	43	X	52
	Added f2 medium (mL L^{-1})	X	1.0	X	X
P4	*Oithona* spp.	50, 50, 50	50, 50, 50	100, 101, 102	51, 53, 52
	Calanus spp.	4, 4, 4	4, 4, 4	4, 5, 5	4, 4, 4
	Temperature (°C)	1	1.5	-1.5	-0.5
	Duration (h)	48	58	49 h	59
	Added f2 medium (mL L^{-1})	1	1	<1	1
P7	*Oithona* spp.	50, 50, 50	50, 50, 50	100, 102, 100	52, 50, 53
	Calanus spp.	4, 4, 4	4, 4, 4	5, 5, 5	4, 4, 4
	Temperature (°C)	1	1.5	-1	2
	Duration (h)	48	69	50	58
	Added f2 medium (mL L^{-1})	1	1	<1	2

The incubation bottles were rinsed three times with the incubation water. To prepare the 20% dilution water (2:10 ratio), 1.6 L 180 µm screened seawater and 6.4 L 0.2 µm filtered seawater was mixed in a 10 L Nalgene transparent PE bottle. The 20% water was then transferred into three 2.5 L Nalgene bottles using the siphoning technique to ensure gentle transfer, and sealed with parafilm with no bubbles in (The Nansen Legacy, 2021b).

Using 100% 180 µm screened seawater three bottles were prepared as the non-diluted (100%) step in the 2-step dilution set-up.

Two additional treatments with copepod grazers were set up. Three bottles with 100% 180 µm screened seawater and added individuals of *Oithona* spp. and three bottles with added individuals of *Calanus* spp. (Table 3). Three bottles with 180 µm screened seawater and added nutrients. The bottles were placed horizontally on a shelf in a cold

room (between -1.5 and 2°C), allowing a gentle rolling with the ship movements. If there was little movement from the ship, the bottles were rotated manually every other hour. The experiments were then terminated after 43-69 hours (Table 3) (Søreide et al., 2022; The Nansen Legacy, 2021a).

At Q3 for station P1, the experiment failed due to issues with temperature control as water heated to 25°C ended up circulating through a jet pump in the plankton wheel used to rotate the bottles and keep the water inside the bottles in motion to prevent settling of plankton. At stations P4 and P7 the bottles were placed horizontally on shelves instead and manually rotated every 5 to 8 hours until the experiment ended (Table 3) (Reigstad et al., 2022).

After the experiments ended, the water was mixed gently before collection. To compare the end incubation samples with the start, samples were taken for flow cytometry, nutrients, ammonium, HPLC, Chl *a*, POC/PON and POP. For the phytoplankton samples, 110 mL of water was sampled and transferred to a brown bottle and 0.5 mL of neutral Lugol's iodine was added, for final concentration of 0.5%. Samples were stored at around 4°C. For microzooplankton samples, 200 mL of sample water was transferred to brown bottles and 3 mL of acidic Lugol's iodine added, for final concentration of 1.5%. Samples were stored in 4°C (The Nansen Legacy, 2020).

2.6 Fluorometric analysis of Chl *a*, methanol extraction

25 mm GF/F filters with Chl *a* samples from Q1 had been frozen and were analysed using fluorometry at Trondheim Biologiske Stasjon (TBS) in February 2024.

15 mL glass centrifuge tubes were filled with 4 mL of 4°C 100% methanol. Working with the lights off, the frozen GF/F filters were placed individually into the tube immediately. The cap was screwed on and the tube was shaken. It was checked that the filters were completely submerged in methanol, before the tubes were placed back into the freezer for 24h.

After 24h the samples were filtered using a 0.2 µm syringefilter into a new tube. Fluorescence was measured on a fluorometer (Turner Design) using the module "chl a-na". A blank was measured by filling a 2 mL vial with 100% methanol. For the Chl *a* samples, the filtered extracts were filled into 2 mL vials and measured in the fluorometer.

Chl *a* concentration was calculated using equation (I):

$$\mu g\ Chl\ a/L = (FL - BL) \times f \times E \times 1000/(V \times 1000) \qquad \text{(I)}$$

Where *FL* is the Chl *a* reading of the sample, *BL* is the Chl *a* reading from the blank, *f* is the calibration factor, *E* is the extraction volume which was 4 mL and *V* is the filtered volume.

2.7 Growth and grazing rates

Phytoplankton and microzooplankton samples from Q3 were counted at Trondheim Biologiske Stasjon (TBS) using Uthermöhl chambers (Uthermöhl, 1958). 50-100 mL of the samples were settled in sedimentation cylinders for 24 hours and then the bottom plate was assessed using inverted microscope (Leica DM IRB). The entire bottom plate was assessed for samples with low cell densities, while samples with higher cell densities only had ¼ or ½ of the plate assessed. For every high density sample, a minimum of 100 individuals of a species were counted. If there was one or two species that were

very dominant compared to other species in the same sample, they were counted using stripes or visual fields separately.

The samples from Q1, Q2 and Q4 were counted by the company Aqua Ecology (Oldenburg, Germany).

Growth and grazing rates were calculated from (Landry & Hassett, 1982) and (Landry et al., 1995). First apparent growth rate for each replicate was calculated according to equation II:

$$k = \frac{1}{t} ln \frac{P_t}{P_0} \qquad \text{(II)}$$

Where *k* is apparent growth rate, *t* is the duration of the experiment in days, P_t is the abundance at the end of the experiment and P_0 is the average abundance of the replicates before the start of the experiment. This was done for all replicates and then the average k value was calculated. Grazing rates were calculated using equation III by accounting for the difference between the diluted sample and the 100% and accounting for the dilution factor, which for the 20% dilutions were 0.8:

$$Grazing\ rate = \frac{Average\ k\ diluted - Average\ k\ 100\%}{Dilution\ factor} \qquad \text{(III)}$$

Growth rates (μ) were calculated for all samples using with equation IV, by using the average *k* and the grazing rate from equation III:

$$Growth\ rates = Average\ k\ 100\% + Grazing\ rate \qquad \text{(IV)}$$

2.8 Species sorting

Species were divided into trophic modes using Kraberg et al., (2010). If the species were not found there, additional literature was used (Table B.1, Appendix B). Species were then further divided into categories based on phylum, shape and size (Table 4), using World Register of Marine Species (WoRMS). More abundant genus like *Thalassiosira* spp. and *Chaetoceros* spp. were kept as their own category to better investigate their growth and how much they are grazed on. The category "Flagellates" consists of unspecified dinoflagellates < 5 μm. The size categories were S (<20 μm), M (20-50 μm) and L (>50 μm).

Table 4: Overview of sorting categories used for the growth and grazing rate calculations. Species were sorted using phylum, shape, and size. Complete overview of all species for each category can be found in attachements (Table B.1, Appendix B).

Phylum	**Sorting category**
Bacillaryophyta	Pennate diatoms > 20 µm Pennate diatoms < 20 µm Centric diatoms > 20 µm Centric diatoms < 20 µm Needleshaped diatoms *Thalassiosira* spp. *Chaetoceros* spp.
Myzozoa	Thecate DF S Thecate DF M Thecate DF L Athecate DF S Athecate DF M Athecate DF L Autotrophic DF
Ciliophora	Loricate S Loricate M Loricate L Aloricate S Aloricate M Aloricate L
Euglenozoa, Telonemia, Radiozoa, Cyanobacteria, Heliozoa, Amoebozoa, Cercozoa, Choanozoa,	Others
Ochrophyta	Silicoflagellates *Dinobryon* spp.
Haptophyta	Haptophyta
Cryptophyta	Cryptophyta
Chlorophyta	Chlorophyta

2.9 Species richness

The Shannon-Wiener diversity index was used to calculate the species richness using number of species in a phylum found at the different cruises and stations (Spellerberg & Fedor, 2003). The diversity index H was calculated using equation V (Shannon & Weaver, 1949):

$$H' = -\sum_{n=1}^{n}(pi^{*}lnp_{i}) \qquad \text{(V)}$$

Where H' is the diversity index, p_i the proportion of each of the species in every phylum and $ln\ p_i$ is the natural logarithm of the proportion. The evenness of species was found using equation VI:

$$E_{H,} = \frac{H'}{lnln\ (S)} \qquad \text{(VI)}$$

Where H' is the Shannon diversity index from equation V and S is the total number of unique species.

2.10 Statistical analyses

Statistical analyses and plotting were done using R: A language and environment for statistical computing (R Core Team, 2021). Two-tailed ANOVA was used to compare growth and grazing over seasons and stations. To further investigate the significance levels, Tukey HSD test was used for identifying which seasons and stations were different from each other. Student's t-test was used to compare treatments with added *Calanus* spp., *Oithona* spp. and nutrients with the 100% treatments. The significance level was set to $P < 0.05$.

3. Results

3.1 Field data

3.1.1 CTD

3.1.1.1 Station P7

For March (Figure 4A), the temperature range was -1.71°C to 2.56°C, the Chl *a* range was up to 0.031 µg/L, with no Chl *a* max detected. The salinity range was 34.46 to 34.92 and the oxygen range was 7.55 mL L^{-1} to 8.92 mL L^{-1}. The surface waters consisted of colder, less saline Arctic Water (ArW) (Figure 5, blue line), that went into warmer Atlantic Water (AW) at around 70 m. At 150 m there was a change to colder Barents Sea Water (BSW).

May had a temperature range of -1.84°C to 1.83°C, Chl *a* was up to 2.19 µg/L, with Chl *a* max at 14 m. Salinity was 34.26 to 34.896 and oxygen was 8.03 mL L^{-1} to 9.42 mL L^{-1} (Figure 4B). Upper 75 m consisted of a stable layer of colder and less saline ArW, with a thermocline at 75m to warmer and more saline AW (Figure 5, Red line).

In August, the temperature range was -1.71°C to 2.63°C, the Chl *a* range was up to 2.71 µg/L, with Chl *a* max at 12 m. The salinity range was 32.59 to 34.95 and the oxygen range was 7.04 mL L^{-1} to 9.09 mL L^{-1} (Figure 4C). The surface layers consisted of Meltwater (MW) with low salinity, that had started to cool, going into colder ArW with higher salinity. At around 75 m, there was a thermocline to warmer and more saline AW (Figure 5, black line).

For December, the temperature range was -1.81°C to 2.79°C, the Chl *a* range was up to 0.069 µg/L, with no Chl *a* max detected. The salinity range was 33.16 to 34.97 and the oxygen range was 5.09 mL L^{-1} to 5.996 mL L^{-1} (Figure 4D). The watermasses consisted of colder, less saline ArW, with a thermocline at 60 m to warmer and more saline AW (Figure 5, green).

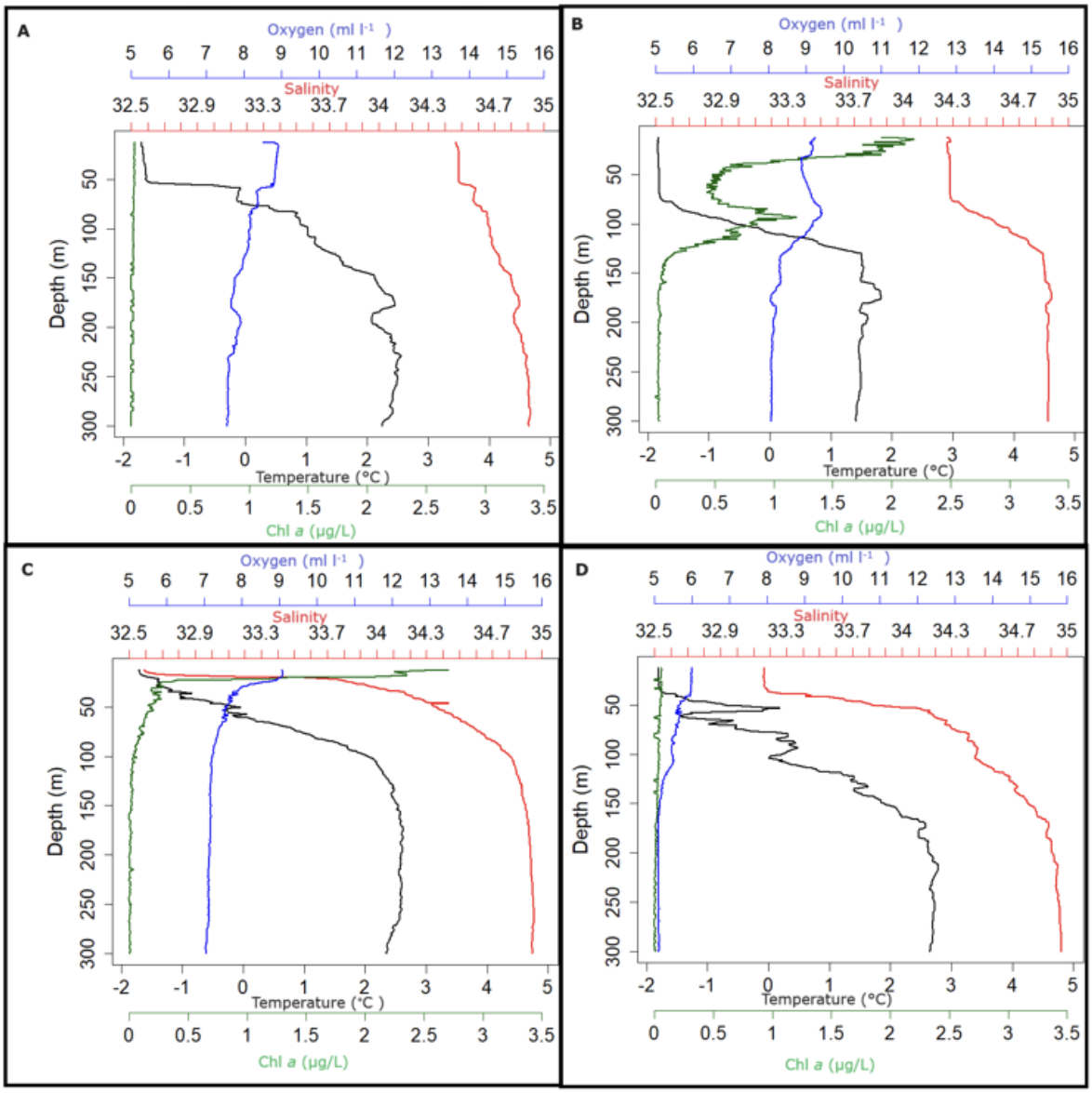


Figure 4: Measurements of temperature (˚C) (black), Chl *a* (µg/L) (green), salinity (red) and oxygen (ml l^{-1}) (blue) at station P7 during A: Q1 (March 2021), B: Q2 (May 2021), C: Q3 (August 2019) and D: Q4 (November/December 2019).

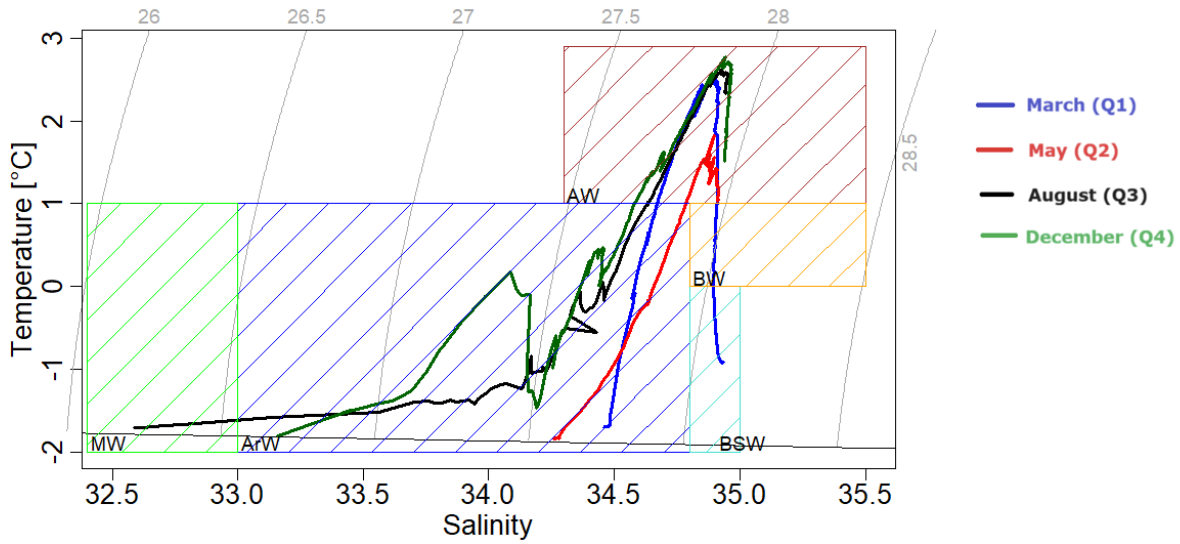


Figure 5: Temperature-salinity plot of watermasses for station P7 in March (Q1) (blue), May (Q2) (red), August (Q3) (black) and December (Q4) (green). Showing presence of Atlantic Water (AW), Arctic Water (ArW), Melt Water (MW), Bottom Water (BW) and Barents Sea Water (BSW).

3.1.1.2 Station P4

For March, the temperature range was -1.77°C to 2.19°C, the Chl *a* range was up to 0.027 µg/L, with no Chl *a* max detected. The salinity range was 34.39 to 34.78 and the oxygen range was 6.55 mL L^{-1} to 7.68 mL L^{-1} (Figure 6A). The surface layers consisted of cold and less saline ArW, with a thermocline at 75 m to warmer and more saline AW. At 225 m there was a shift to colder and more saline BW (Figure 7, blue line).

May had a temperature range of -1.84°C to 1.96°C, the Chl *a* range was up to 0.631 µg/L with no Chl *a* max detected. The salinity range was 34.38 to 34.79 and the oxygen range was 7.90 mL L^{-1} to 9.28 mL L^{-1} (Figure 6B). The surface waters were dominated by cold ArW, with a thermocline at around 75 m to warmer and more saline AW. At around 215 m there was a shift to colder BW (Figure 7, red line).

For August, the temperature range was -1.82°C to 0.986°C, the Chl *a* range was 0.040 µg/L to 3.24 µg/L, with the Chl *a* max at 38 m. The salinity range was 33.12 to 34.81 and the oxygen range was 7.92 mL L^{-1} to 10.25 mL L^{-1} (Figure 6C). The first 15 m consisted of MW, with low salinity and warmer temperatures, that turned into colder and more saline ArW, with more saline BSW at the bottom (Figure 7, black line).

In December the temperature range was -1.86°C to -0.456°C, the Chl *a* range was up to 0.035 µg/L, with no Chl *a* max detected. The salinity range was 34.12 to 34.74. The oxygen measurement was not used due to incorrect values (Figure 6D). The watermasses consisted of cold ArW that was stable for the upper 80 m, but got colder and more saline, with a shift to more saline BSW at around 225 m depth (Figure 7).

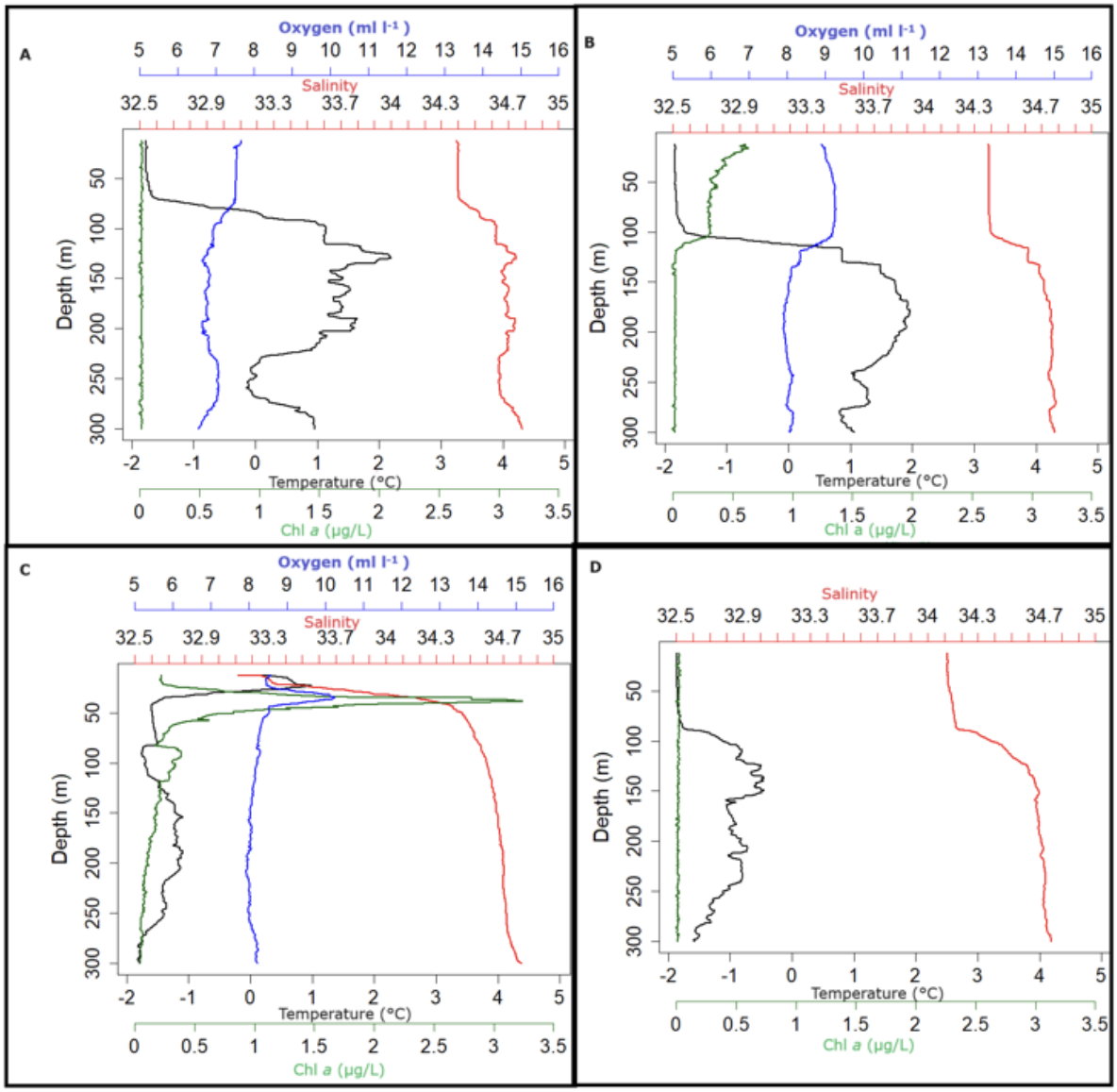


Figure 6: Measurements of temperature (black), Chl *a* (green), salinity (red) and oxygen (blue) for Station P4 during A: Q1 (March 2021), B: Q2 (May 2021), C: Q3 (August 2019) and D: Q4 (November/December 2019).

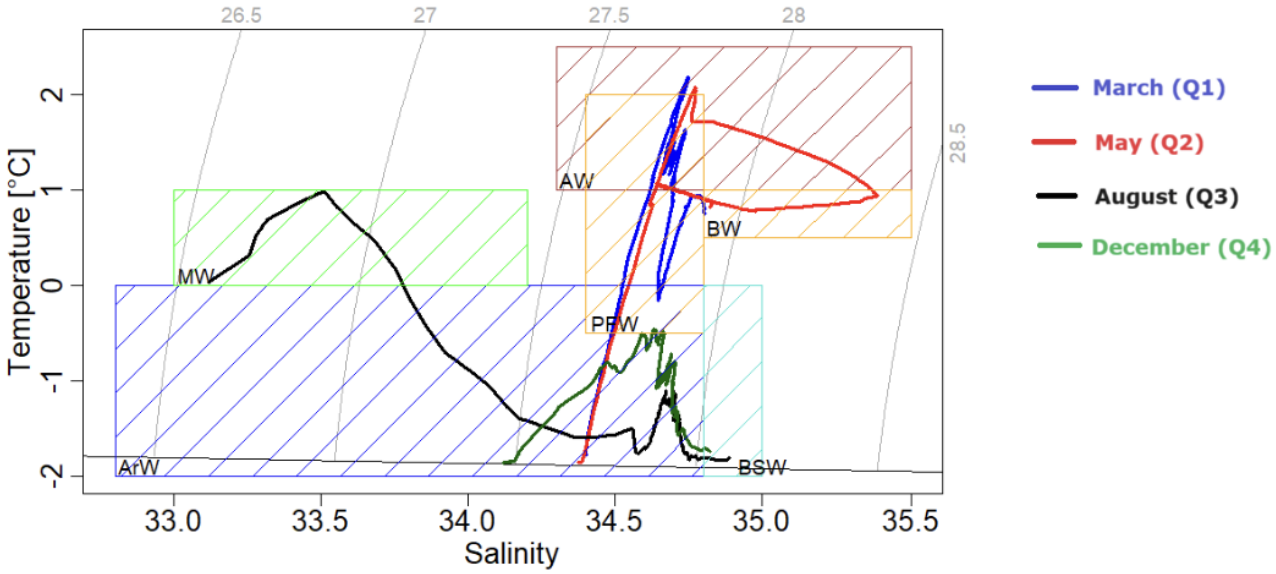


Figure 7: TS (Temperature salinity)-plot of the watermasses for the temperature and salinity ranges for station P4 and cruises Q1 (blue), Q2 (red), Q3 (black) and Q4 (green). Showing presence of Atlantic Water (AW), Arctic Water (ArW), Melt Water (MW), Bottom Water (BW), Polar Front Water (PFW) and Barents Sea Water (BSW). Watermasses characteristics are defined in Table B.2.

3.1.1.3 Station P1

May had a warmer temperature range of 1.41°C to 1.79°C, the Chl *a* range fluctuated more at 0.054 µg/L to 1.10 µg/L, with no distinct Chl *a* max detected. The salinity range was 34.911 to 34.918 and the oxygen range was 8.306 mL L^{-1} to 8.616 mL L^{-1} (Figure 8A). The watermasses consisted of high salinity and higher temperature AW, that was stable throughout the water column (Figure 9).

For December there was more wintery conditions with a temperature range of 0.706°C to 1.795°C, the Chl *a* range was up to 0.072 µg/L, with no Chl *a* max detected. The salinity range was 34.87 to 34.94 and the oxygen range was 8.83 mL L^{-1} to 13.99 mL L^{-1} (Figure 8B). The water colum was mixed in May with AW. In December it was mixed AW down to 225 m where there was a thermocline to colder BW (Figure 9).

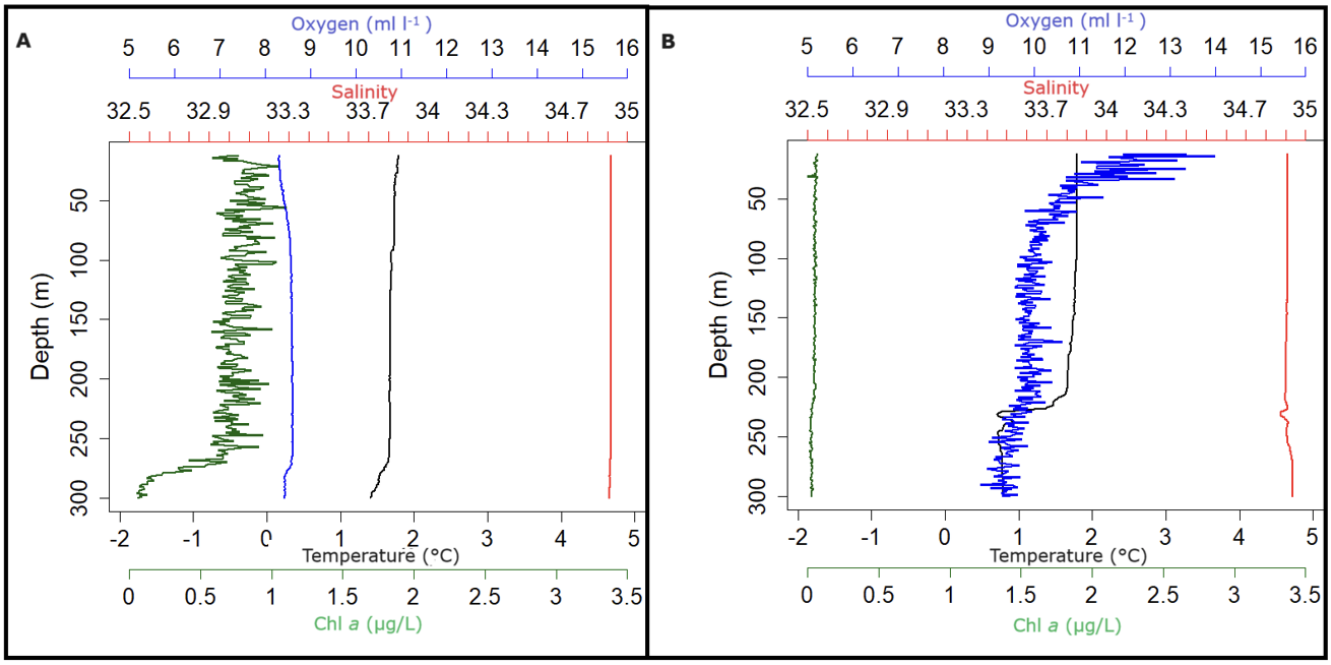


Figure 8: Measurements of temperature (black), Chl a (green), salinity (red) and oxygen (blue) for Station P1 during A: the May cruise Q2 and B: December cruise Q4.

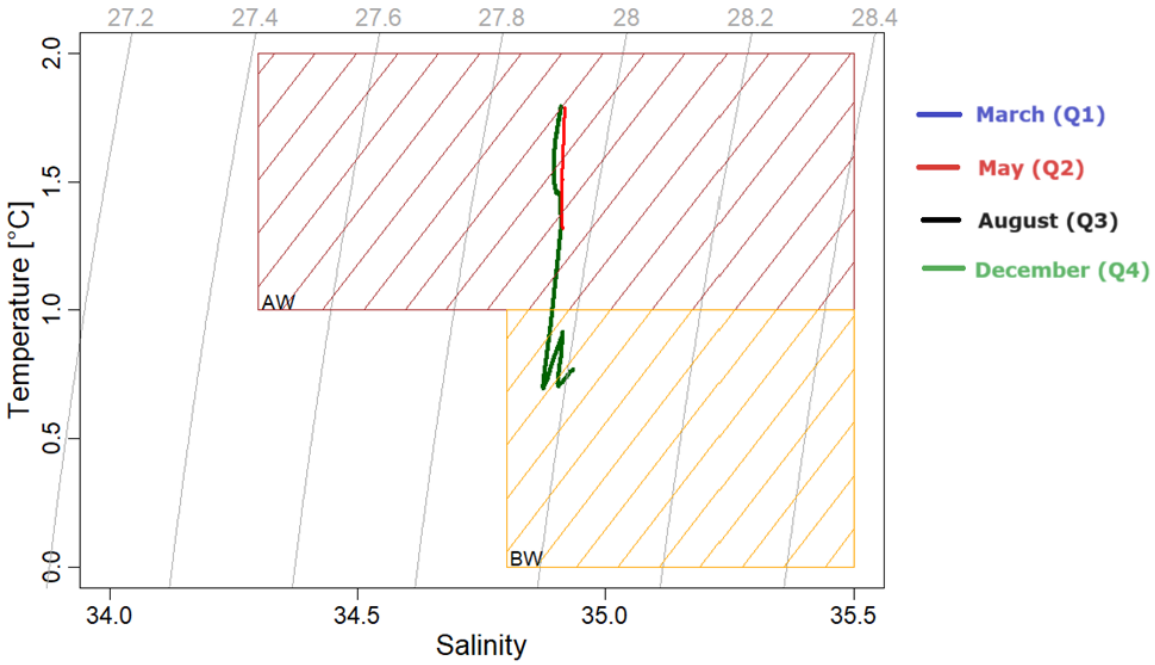


Figure 9: TS (Temperature-Salinity) plot of the watermasses from station P1 for Cruises Q2 (red) and Q4 (green). Showing presence of Atlantic Water (AW) and Bottom Water (BW).

3.1.2 Chl *a* data

3.1.2.1 Station P7

The Chl *a* concentrations measured in March (red), May (green), August (blue) and December (purple) at Station P7 can be seen in Figure 10. In the 100% there was an increase in the Chl *a* concentration from March to May (*t*-test, $p<0.05$) and a decrease from August to December (*t*-test, $p<0.05$). There were no significant differences between the 100% end samples and the treatments with added *Calanus* spp. (T-test, $p>0.05$), *Oithona* spp. (*t*-test, $p>0.05$) and nutrients (*t*-test, $p>0.05$) for any of the seasons.

In March the Start Chl *a* concentration was 0.033 (SD 0.002) µg/L and there was no significant increase after the incubation time for the 100% end at 0.032 (SD 0.004) µg/L (*t*-test, $p=0.82$). In May the Chl *a* Start concentration was 0.29 (SD 0.02) µg/L, with there being no significant difference between the Start and the 100% end concentration at 0.313 (SD 0.01) µg/L (*t*-test, $p=0.34$). Between May and August there were no significant difference (*t*-test, $p=0.15$). The highest Chl *a* concentrations were measured in August with Start Chl *a* concentration of 0.687 (SD 0.013) µg/L, with no significant difference between Start and 100% end at 0.513 (SD 0.12) µg/L (*t*-test, $p=0.19$). In December the lowest Chl *a* concentrations were measured, with no differences between the Start Chl *a* concentration at 0.023 (SD 0.005) µg/L and 100% end at 0.02 (SD 0) µg/L (*t*-test, $p=0.42$).

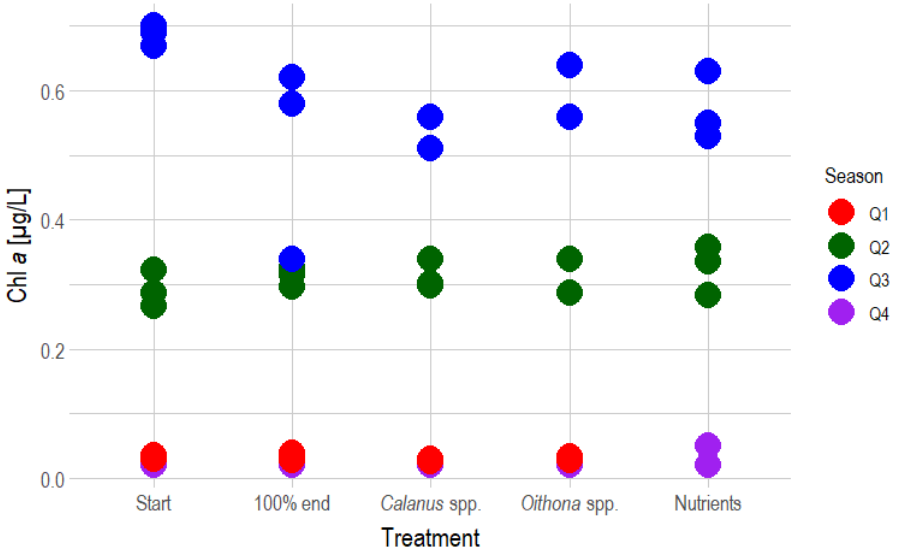


Figure 10: Chl *a* concentrations at station P7 for each of the three replicates of each treatments; Start, 100% end, added *Calanus* spp., added *Oithona* spp. and added nutrients. Q1 (red) was the March cruise, Q2 (green) the May cruise, Q3 (blue) the August cruise and Q4 (purple).

3.1.2.2 Station P4

Figure 11 shows the measured Chl *a* concentrations from March (red), May (green), August (blue) and December (purple). There was an increase in the Chl *a* concentrations measured in 100% end sampes from March to May (*t*-test, $p<0.05$) and from May to

August (*t*-test, $p<0.05$). There were no significant differences between the 100% end samples and the treatments with added *Calanus* spp. (*t*-test, $p>0.05$), *Oithona* spp. (*t*-test, $p>0.05$) and nutrients (*t*-test, $p>0.05$) for any of the seasons.

In March the Start Chl *a* concentration was 0.016 (SD 0.002) µg/L with no significant difference with the 100% end sample at 0.015 (SD 0.008) µg/L (*t*-test, $p=0.32$). May had the highest Chl *a* concentrations with a Start concentration of 1.94 (SD 0.033) µg/L, with an increase in the Chl *a* concentration after incubation for the 100% end at 3.38 (SD 0.091) µg/L (*t*-test, $p<0.05$). In August the Start Chl *a* concentration was 0.13 (SD 0.029) µg/L, with a slight increase in the 100% end sample at 1.11 (SD 0.43) µg/L, that was not significant (*t*-test, $p=0.09$). From August to December there was a decrease in the Chl *a* concentration, this was not significant (*t*-test, $p=0.07$). In December the lowest Chl *a* concentrations were measured and there was no change in Chl *a* concentration between the Start and the 100% at 0.001 (SD 0.005) µg/L (*t*-test, $p=0.43$).

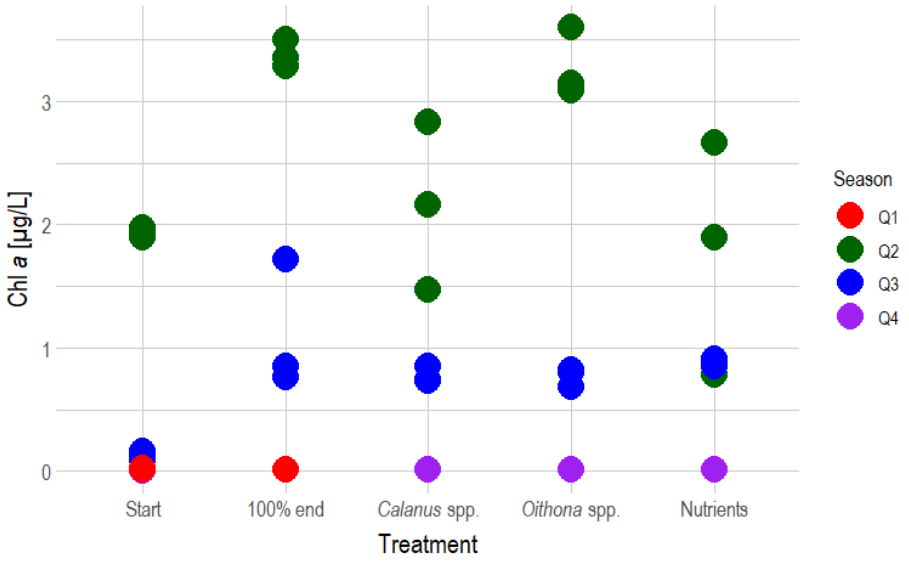


Figure 11: Chl *a* concentrations at station P4 for each of the three replicates of each treatments; Start, 100% end, added *Calanus* spp., added *Oithona* spp. and added nutrients. Q1 (red) was the March cruise, Q2 (green) the May cruise, Q3 (blue) the August cruise and Q4 (purple)

3.1.2.3 Station P1

Figure 12 shows the Chl *a* concentrations measured at station P1 for cruises Q2 (May) and Q4 (December). There was a decrease in Chl *a* concentration in 100% end from May to December (*t*-test, $p<0.05$). There were no significant differences between the 100% end samples and the treatments with added *Calanus* spp. (*t*-test, $p>0.05$), *Oithona* spp. (*t*-test, $p>0.05$), and nutrients (*t*-test, $p>0.05$) for both cruises.

In May the Start Chl *a* concentration was 0.98 (SD 0.35) µg/L and there was a non significant increase in the concentration after incubation for the 100% at 1.94 (SD 0.07) µg/L (*t*-test, $p=0.054$). There was a trend towards *Oithona* spp. having higher Chl *a*

concentrations, however, it was not significant (*t*-test, *p*=0.053). In December the Start Chl *a* concentration and the 100% end was the same at 0.02 (SD 0) µg/L.

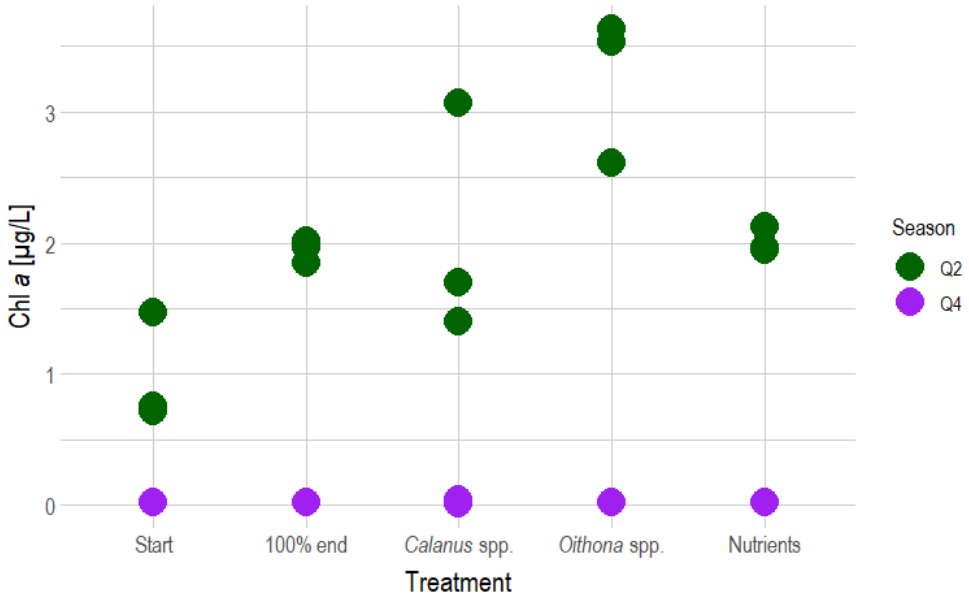


Figure 12: Chl *a* concentrations for each of the three replicates of each treatments; Start, 100% end, added Calanus spp., added Oithona spp. and added nutrients. Q2 (green) was the May cruise and Q4 (purple) was the December cruise.

3.2 Abundance of phytoplankton and microzooplankton species and relative abundance

3.2.1 Station P7

At Station P7 for the microzooplankton there was an increase in abundance in 100% end from the lowest abundance found in March to the highest abundance found in May (*t*-test, $p<0.05$). From May to August there was a decrease in abundance (*t*-test, $p<0.05$) and from August to December there was an increase in abundance (*t*-test, $p<0.05$), with December having the second highest abundance. From December to March there was a decrease in the abundance of microzooplankton (*t*-test, $p<0.05$).

Phytoplankton had an increase in abundance in 100% end from March to May (*t*-test, $p<0.05$), where the highest abundances were found. Followed by a decrease in abundance from May to August (*t*-test, $p<0.5$). The abundances were not significantly different between August and December (*t*-test, $p=0.08$) and December and March (*t*-test, $p=0.07$).

In March the Start abundance of microzooplankton was 3.9 (SD 0.49) cells/mL, with no significant change after the incubation time for the abundance in the 100% end at 2.7 (SD 0.48) cells/mL (*t*-test, $p=0.07$) (Figure 13A). For all of the samples Athecate DF S (<20 µm) were the most dominating group, with *Gymnodinium* spp. being the dominating species. There were no significant changes in abundance for any of the treatments with *Calanus* spp. at 2.2 (SD 0.68) cells/mL and *Oithona* spp. at 2.4 (SD 0.46) cells/mL) compared to the 100% end (*t*-test, $p=0.48$ and 0.59, respectively), but there was a trend towards lower abundances after incubation. Mostly due to lower

abundance of Aloricate S (<20 µm) and 'Others' for the 100% end, *Calanus* spp., and *Oithona* spp. treatments (Figure 13B).

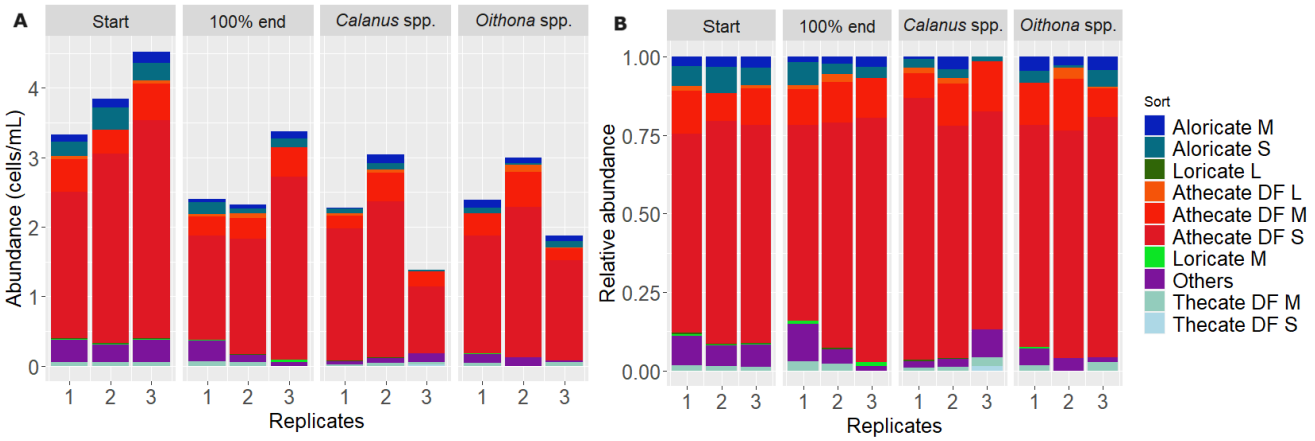


Figure 13: A) Absolute abundance [cells/mL] of microzooplankton for three replicates of; Start, 100% end, *Calanus* spp., and *Oithona* spp. at station P7 in March (cruise Q1). B) Relative abundance of microzooplankton for three replicates of Start, 100% end, *Calanus* spp., and *Oithona* spp. at station P7 in March (cruise Q1).

The Start abundance of the phytoplankton in March was 0.72 (SD 0.09) cells/mL with no significant difference to the 100% end abundance at 0.54 (SD 0.09) cells/mL (*t*-test, p=0.12) (Figure 14A). For all the samples Cryptophyta was the most dominating group, with *Leucocryptos marina* being the most dominating species. There were no significant differences in abundance for any of the treatments with *Calanus* spp. at 0.33 (SD 0.06) cells/mL, and *Oithona* spp. at 0.41 (SD 0.021) cells/mL, compared to the 100% end (*t*-test, p=0.059 and 0.17, respectively). There was a trend towards decreasing abundances in *Calanus* spp., and *Oithona* spp, compared to the 100%, with the lower abundance found for *Calanus* spp. This decrease in abundance was mostly due to lower abundances of Cryptophyta and 'Others'. There was also a shift to more abundance of Centric diatoms < 20 µm for 100% end and *Calanus* spp., and Haptophyta for 100% end and *Oithona* spp., compared to Start (Figure 14B).

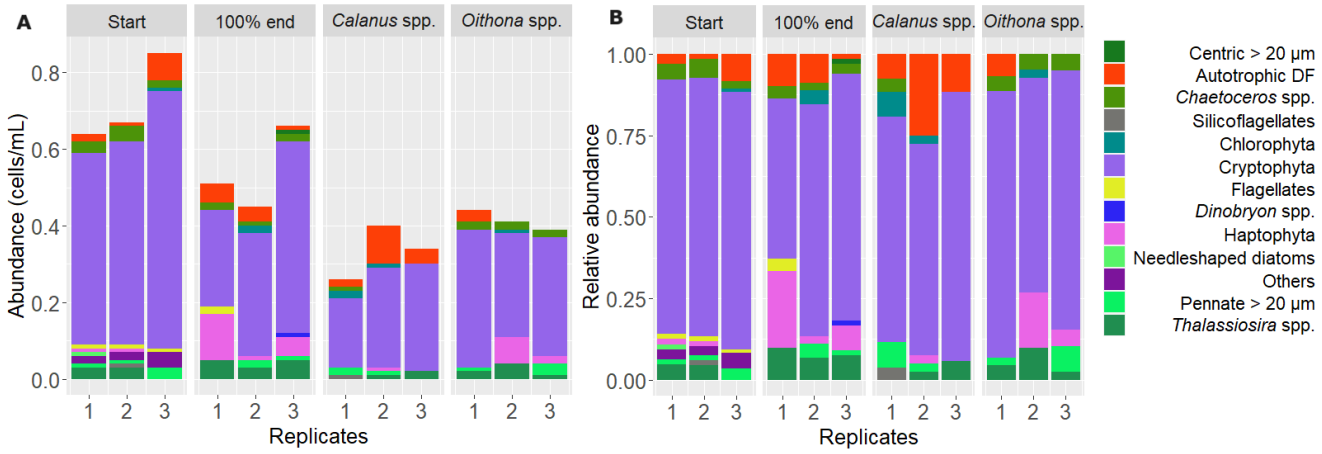


Figure 14: A) Absolute abundance [cells/mL] of phytoplankton for three replicates of; Start, 100% end, *Calanus* spp., and *Oithona* spp. at station P7 in March (cruise Q1). B) Relative abundance of phytoplankton for three replicates of Start, 100% end, *Calanus* spp., and *Oithona* spp. at station P7 in March (cruise Q1).

In May there was an increase in the abundance of microzooplankton with a Start abundance of 25.8 (SD 5.6) cells/mL, there was no significant change in the abundance for the 100% end sample at 23.0 (SD 0.37) cells/mL (*t*-test, p=0.56) (Figure 15A). There was decreased abundance for *Calanus* spp. at 21.6 (SD 0.47) cells/mL, compared to the 100% (*t*-test, p<0.05). There was no significant decrease in the *Oithona* spp. treatment at 20.9 (SD 1.3) cells/mL (*t*-test, p=0.14). Athecate DF S were the dominating group in all samples, with *Gyrodinium* spp. (<20µm) being the most abundant species. The observed decrease in *Calanus* spp. was mostly due to Loricate M (20-50 µm) and Aloricate M (20-50 µm). In *Oithona* spp. there was a shift to less abundance of 'Others' and higher abundance of Aloricate S (<20µm) (Figure 15B).

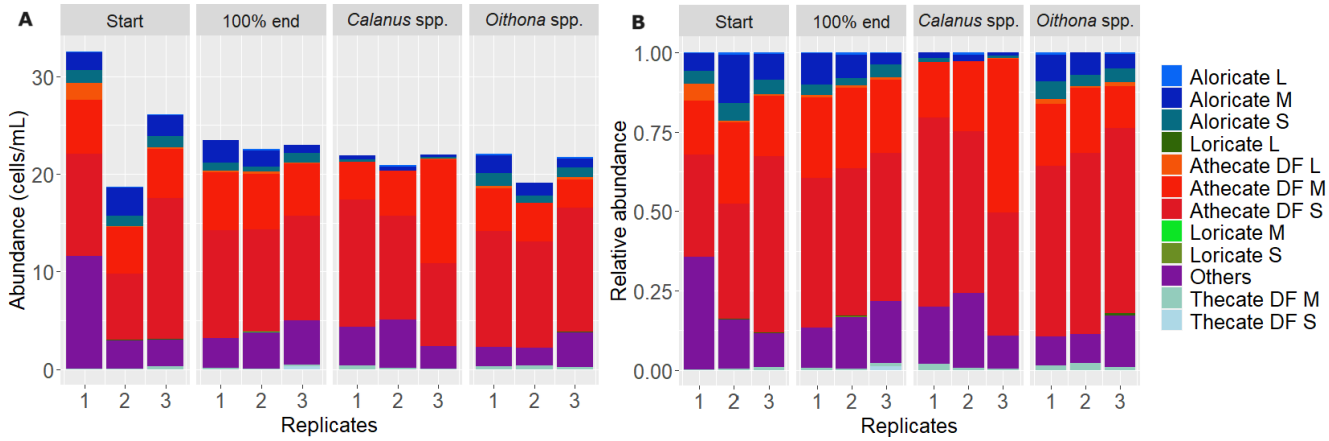


Figure 15: A) Absolute abundance [cells/mL] of microzooplankton for three replicates of; Start, 100% end, *Calanus* spp., and *Oithona* spp. at station P7 in May (cruise Q2). B) Relative abundance of microzooplankton for three replicates of Start, 100% end, *Calanus* spp., and *Oithona* spp. at station P7 in May (cruise Q2).

The abundance of phytoplankton in May was higher than in March with a Start abundance of 606 (SD 151) cells/mL (Figure 16A). There was a decrease in the 100% end sample at 66.8 (SD 6.6) cells/mL (*t*-test, p<0.05). There were no significant differences between the treatments with *Calanus* spp. at 47.3 (SD 11) cells/mL, and *Oithona* spp. at 48.8 (SD 13) cells/mL, compared to the 100% end (*t*-test, p=0.12 and 0.17, respectively). The decrease in abundance from Start to the 100% end was due to 'Flagellates' dominating the Start samples. In the 100%, Calanus spp. and Oithona spp. there was not only dominance of 'Flagellates', but also higher abundances of Pennate diatoms > 20 µm, Cryptophyta, Chlorophyta and Centric diatoms > 20 µm (Figure 16B).

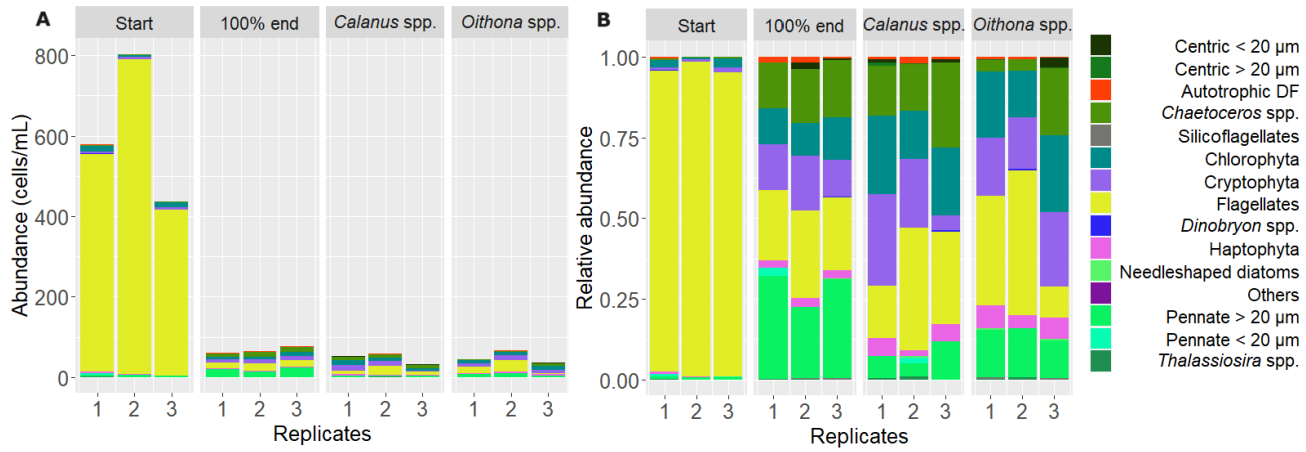


Figure 16: A) Absolute abundance [cells/mL] of phytoplankton for three replicates of; Start, 100% end, *Calanus* spp., and *Oithona* spp. at station P7 in May (cruise Q2). B) Relative abundance of phytoplankton for three replicates of Start, 100% end, *Calanus* spp., and *Oithona* spp. at station P7 in May (cruise Q2).

Microzooplankton in August had a Start abundance of 7.5 (SD 0.40) cells/mL, with a non significant increase in abundance for the 100% end sample at 9.9 (SD 0.23) cells/mL (*t*-test, p=0.071) (Figure 17A). There was no significant difference in *Calanus* spp. at 5.9 (SD 1.4) cells/mL, compared to the 100% end (*t*-test, p=0.052). There was a decrease in the abundance for *Oithona* spp. at 8.2 (SD 0.45) cells/mL compared to the 100% end (*t*-test, p<0.05). In all samples Athecate DF M (20-50 µm) and Loricate M (20-50 µm) were the most dominating groups, with *Gymnodinum* spp. and *Acanthostomella norvegica* being the most abundant species, respectively. For the 100% end there was a higher dominance of Aloricate S (<20 µm) and Aloricate L (>50 µm). The species composition for *Calanus* spp. and *Oithona* spp. was similar to 100% end with lower abundances (Figure 17B).

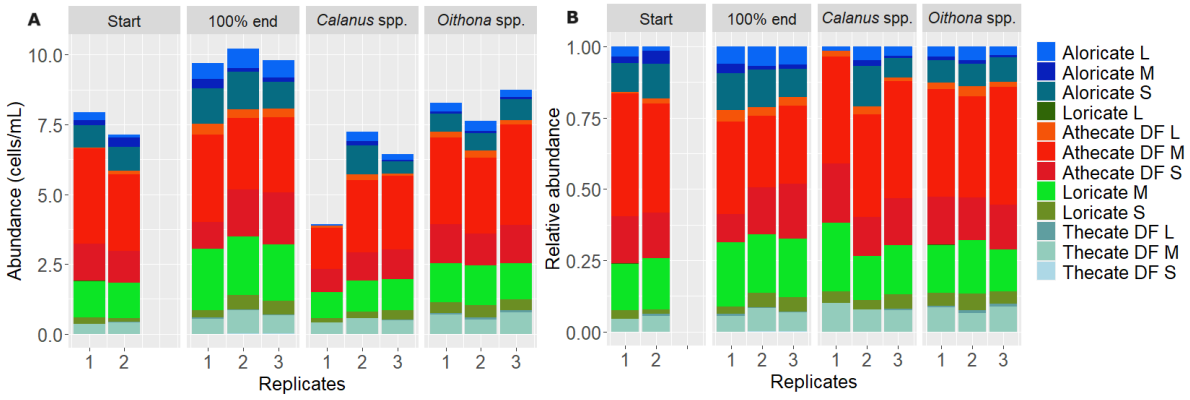


Figure 17: A) Absolute abundance [cells/mL] of microzooplankton for two replicates of Start and three replicates of; 100% end, *Calanus* spp., and *Oithona* spp. at station P7 in August (cruise Q3). B) Relative abundance of microzooplankton for two replicates of Start, and three replicates of 100% end, *Calanus* spp. and *Oithona* spp. at station P7 in August (cruise Q3).

The Start abundance of phytoplankton in August was 21.1 (SD 4.2) cells/mL with no significant difference compared to the 100% end abundance at 23.1 (SD 4.4) cells/mL (*t*-test, p=0.73) (Figure 18A). There was a non significant decrease in abundance for *Calanus* spp. at 19.5 (SD 3.8) cells/mL and *Oithona* spp. at 19.3 (SD 2.6) cells/mL, compared to 100% end (*t*-test, p=0.44 and 0.37, respectively). For all samples *Thalassiosira* spp. was the most dominating group. In 100% end, *Calanus* spp. and

Oithona spp. the community composition was similar with a trend towards higher abundance of Centric diatoms > 20 µm (Figure 18B).

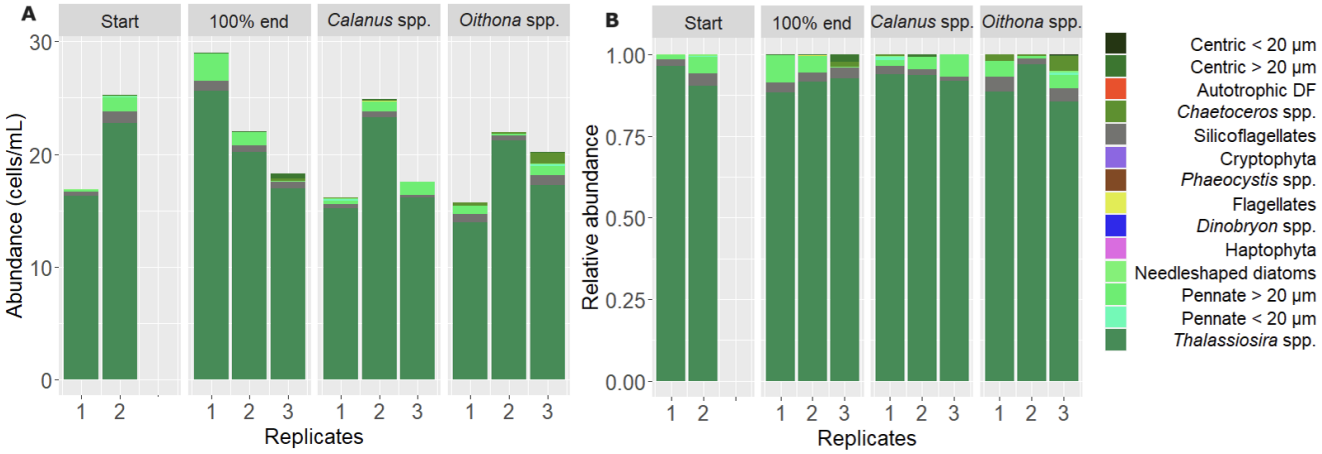


Figure 18: A) Absolute abundance [cells/mL] of phytoplankton for two replicates Start and three replicates of; 100% end, *Calanus* spp., and *Oithona* spp. at station P7 in August (cruise Q3). B) Relative abundance of phytoplankton for three replicates of Start, 100% end, *Calanus* spp., and *Oithona* spp. at station P4 in August (cruise Q3).

In December the Start abundance of microzooplankton was 10.4 (SD 5.7) cells/mL, with a non significant increase in the 100% end sample at 25.3 (SD 1.3) cells/mL (*t*-test, p=0.060) (Figure 19A). For all the samples Athecate DF S (<20 µm) was the most dominating group, with *Gymnodinium* spp. being the most abundant species. There was no significant differences in *Calanus* spp. at 22.0 (SD 18) cells/mL, and *Oithona* spp. at 14.2 (SD 6.9) cells/mL, compared to the 100% end (*t*-test, p=0.82 and 0.15, respectively). For all samples except replicate 3 of *Calanus* spp. the species composition was similar, in replicate 3 of *Calanus* spp. there was only abundance of 'Others' (Figure 19B).

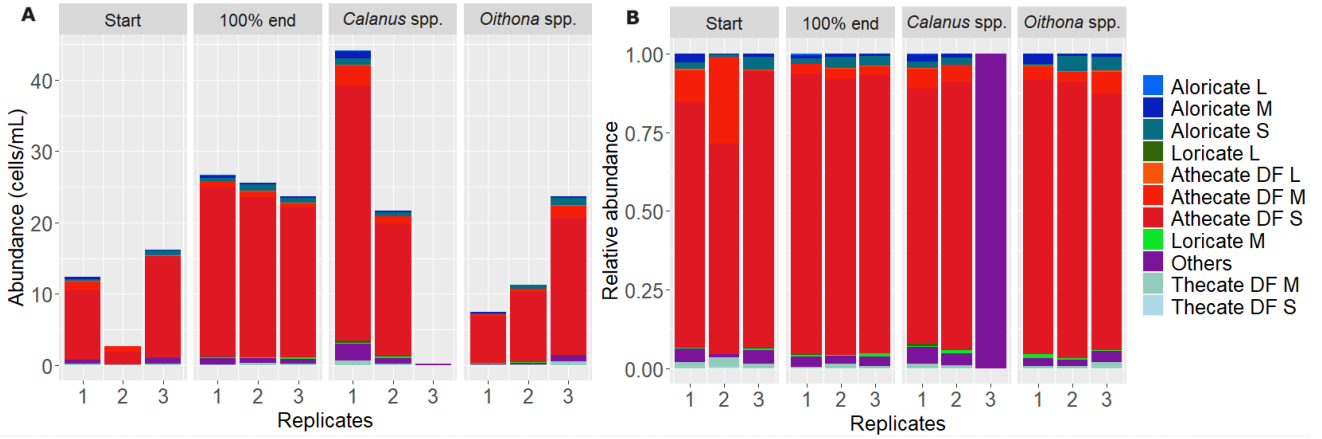


Figure 19: A) Absolute abundance [cells/mL] of microzooplankton for three replicates of; Start, 100% end, *Calanus* spp., and *Oithona* spp. at station P7 in December (cruise Q4). B) Relative abundance of microzooplankton for three replicates of Start, 100% end, *Calanus* spp. and *Oithona* spp. station P7 in December (cruise Q4).

For phytoplankton the Start abundance in December was 300 (SD 225) cells/mL, with no significant difference with the 100% end at 346 (SD 139) cells/mL (*t*-test, p=0.82) (Figure 20A). There was a non significant decrease in abundance for *Calanus* spp. at 60.8 (SD 73) cells/mL, and *Oithona* spp. at 50.6 (SD 62) cells/mL compared to 100%

end (*t*-test, p=0.081 and 0.077). For all samples, 'Flagellates' was the dominating group, except for replicate 2 for Start, replicate 1 and 2 for *Calanus* spp. and replicate 1 and 2 for *Oithona* spp. For *Calanus* spp. and *Oithona* spp. there was presence of Autotrophic DF and Haptophyta, which was not present in Start and 100% end (Figure 20B).

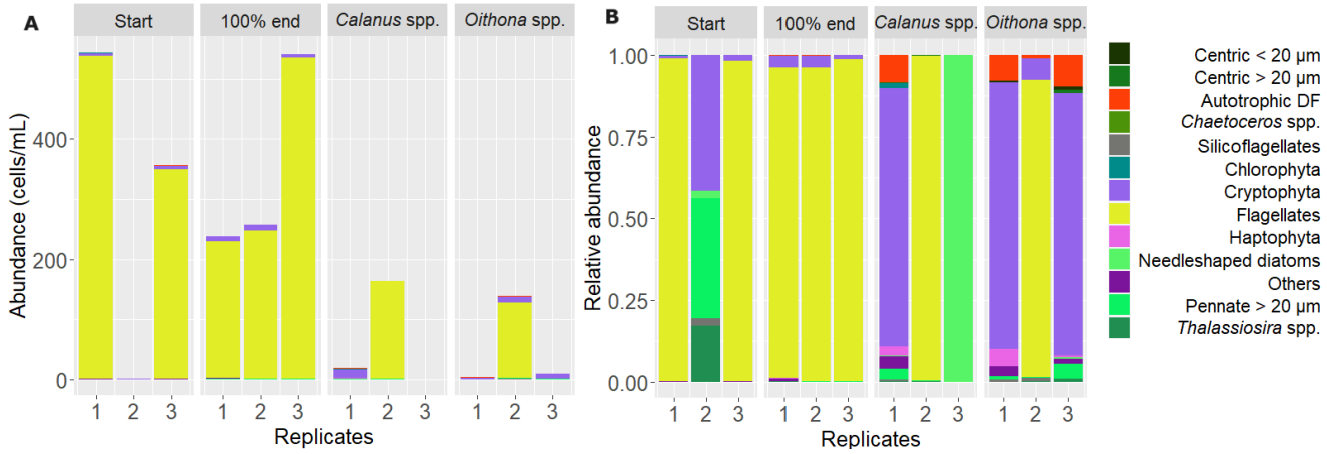


Figure 20: A) Absolute abundance [cells/mL] of phytoplankton for three replicates of; Start, 100% end, *Calanus* spp., and *Oithona* spp. at station P7 in December (cruise Q4). B) Relative abundance of phytoplankton for three replicates of Start, 100% end, *Calanus* spp., and *Oithona* spp. at station P7 in December (cruise Q4).

3.2.2 Station P4

The abundance of microzooplankton increased from the lowest measured abundance in March to the highest in May (*t*-test, p<0.05). The abundances in May were higher than August, but the difference was not significant (*t*-test, p=0.64). From August to December there was an increase in abundance (*t*-test, p<0.05). December had higher abundance of microzooplankton than March, but the decrease was not significant (*t*-test, p=0.32).

Phytoplankton abundances increased from March to May (*t*-test, p<0.05). The highest abundances were found in May and there was a decrease in abundance in August (*t*-test, p<0.05). From August to December there was a decrease in abundance (*t*-test, p<0.05), with December having the lowest phytoplankton abundance. March had higher abundance than December, but the increase was not significant (*t*-test, p=0.29).

In March the Start abundance of microzooplankton was 1.5 (SD 0.24) cells/mL and there was a non-significant decrease in abundance for the 100% end at 0.90 (SD 0.049) cells/mL, compared to Start (*t*-test, p=0.075) (Figure 21A). For both Start and 100% end there was dominance of Athecate DF S (<20 µm), with *Gymnodinium* spp. being the most abundant species. In the 100% end there was less abundance of Aloricate S (<20 µm) and Athecate DF S compared to Start (Figure 21B).

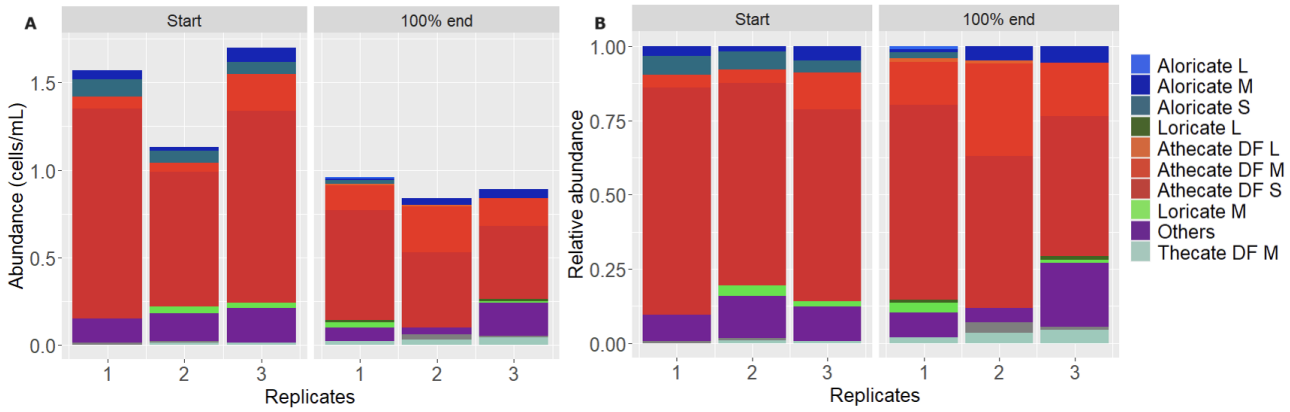


Figure 21: A) Absolute abundance [cells/mL] of microzooplankton for three replicates of; Start, 100% end, *Calanus* spp., and *Oithona* spp. at station P4 in March (cruise Q1). B) Relative abundance of microzooplankton for three replicates of Start, 100% end, *Calanus* spp., and *Oithona* spp. at station P4 in March (cruise Q1).

The Start abundance of phytoplankton in March was 0.50 (SD 0.082) cells/mL, with there being a non significant decrease in abundance for the 100% end at 0.42 (SD 0.033) cells/mL (*t*-test, p=0.29) (Figure 22A). The most dominating group for Start and 100% end was Cryptophyta, with *Leucocryptos marina* being the most abundant species. From Start to the 100% end the species composition was similar, with less abundance of Cryptophyta and 'Others' in the 100% end (Figure 22B).

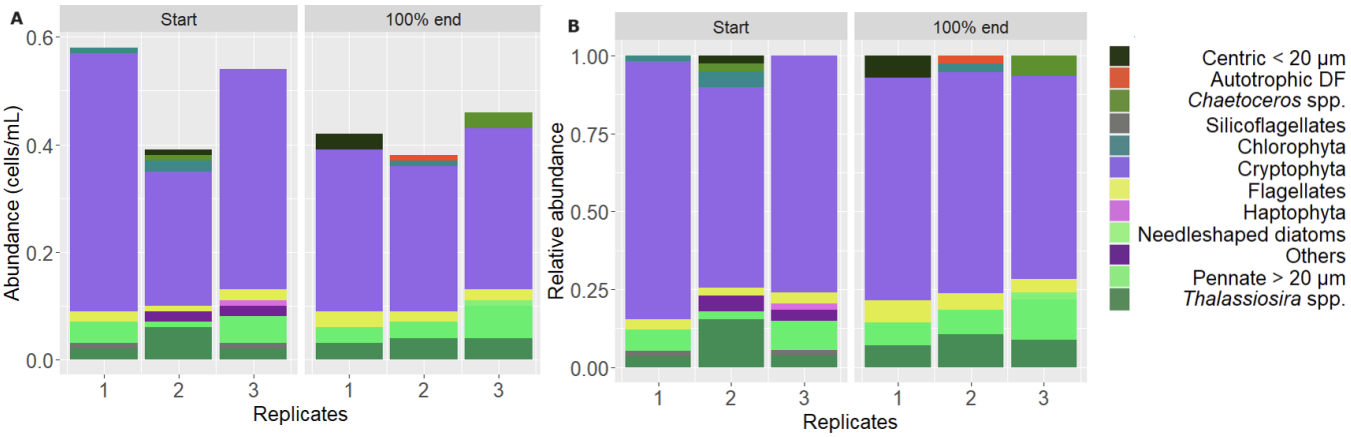


Figure 22: A) Absolute abundance [cells/mL] of phytoplankton for three replicates of; Start, 100% end, *Calanus* spp., and *Oithona* spp. at station P4 in March (cruise Q1). B) Relative abundance of phytoplankton for three replicates of Start, 100% end, *Calanus* spp., and *Oithona* spp. at station P4 in March (cruise Q1).

In May the microzooplankton Start abundance was 115 (SD 23) cells/mL and there was a decrease in abundance for the 100% end at 14.3 (SD 2.2) cells/mL compared to the Start sample (*t*-test, p<0.05) (Figure 23A). There was a non significant increase in abundance for *Calanus* spp. at 47.0 (SD 4.0) cells/mL, and *Oithona* spp. at 39.3 (SD 12) cells/mL, compared to 100% end (*t*-test, p=0.16 and 0.91, respectively). For all samples Athecate DF S (<20 µm) was the dominating group, with *Gymnodinium* spp. being the most abundant species. In all samples there were high abundances of 'Others'. 100% end, *Calanus* spp., and *Oithona* spp. compared to Start had lower abundances of Athecate DF S and M that contributed to the decrease in overall abundance (Figure 23B).

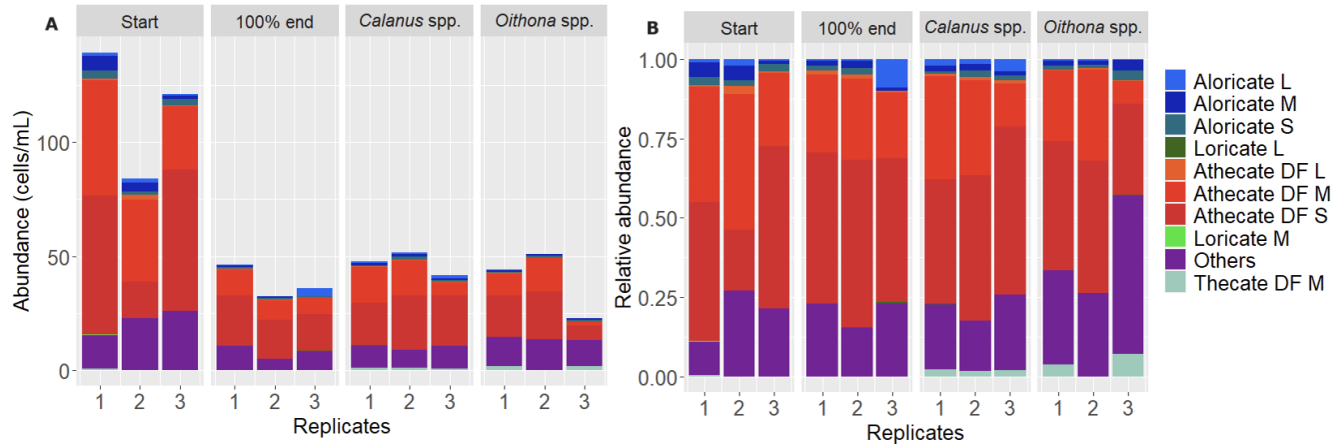


Figure 23: A) Absolute abundance [cells/mL] of microzooplankton for three replicates of; Start, 100% end, *Calanus* spp., and *Oithona* spp. at station P4 in May (cruise Q2). B) Relative abundance of microzooplankton for three replicates of Start, 100% end, *Calanus* spp., and *Oithona* spp. at station P4 in May (cruise Q2).

Phytoplankton Start abundance in May was 2132 (SD 203) cells/mL with a decrease in abundance compared to the 100% end at 677 (SD 53) cells/mL (*t*-test, $p<0.05$) (Figure 24A). There were no significant differences in *Calanus* spp. at 535 (SD 102) cells/mL, and *Oithona* spp. at 607 (SD 52) cells/mL compared to 100% end (*t*-test, $p=0.18$ and 0.25, respectively). The decrease in abundance was mostly due to reduction in abundance of 'Flagellates' (<5 µm). The phytoplankton composition was similar for 100%, *Calanus* spp., and *Oithona* spp. (Figure 24B).

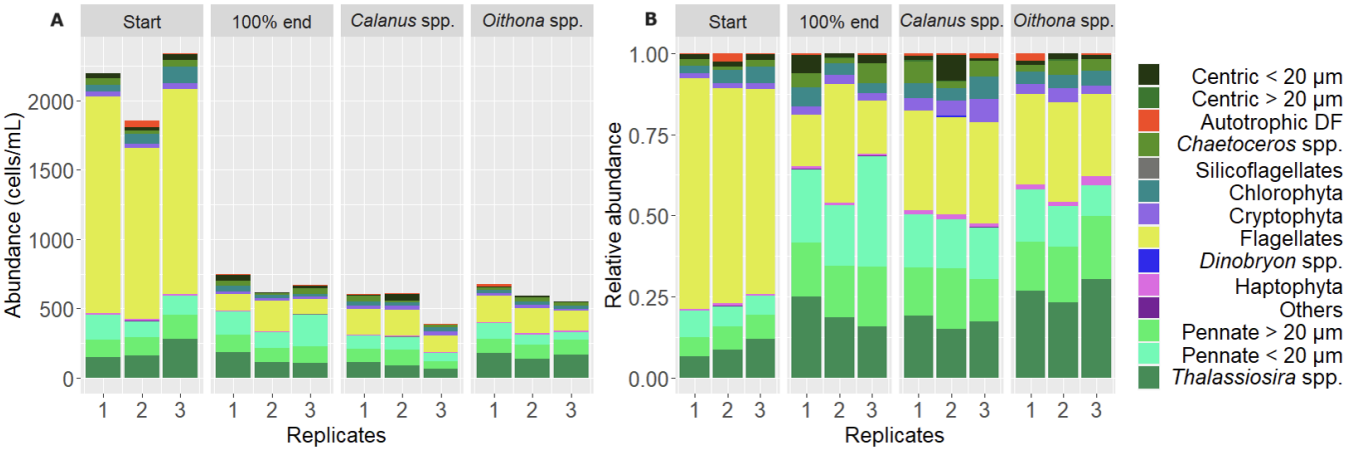


Figure 24: A) Absolute abundance [cells/mL] of phytoplankton for three replicates of; Start, 100% end, *Calanus* spp., and *Oithona* spp. at station P4 in May (cruise Q2). B) Relative abundance of phytoplankton for three replicates of Start, 100% end, *Calanus* spp., and *Oithona* spp. at station P4 in May (cruise Q2).

In August the microzooplankton Start abundance was 11.2 (SD 2.2) cells/mL (Figure 25A). There was an increase in abundance for the 100% end at 35.8 (SD 1.6) cells/mL compared to Start (*t*-test, $p<0.05$). Compared to the 100% end there was a decrease in abundance for *Calanus* spp. at 16.6 (SD 1.8) cells/mL) and *Oithona* spp. at 15.0 (SD 1.0) cells/mL (*t*-test, $p<0.05$). For all samples Athecate DF M (20-50 µm) was the dominant group, with *Gymnodinium* spp. being the most abundant species. The increase in abundance for 100% was mostly due to Athecate DF M. In *Calanus* spp. and *Oithona*

spp. the species composition was similar to 100% end, with lower abundances of Athecate DF M and S, Loricate M and Aloricate S (Figure 25B).

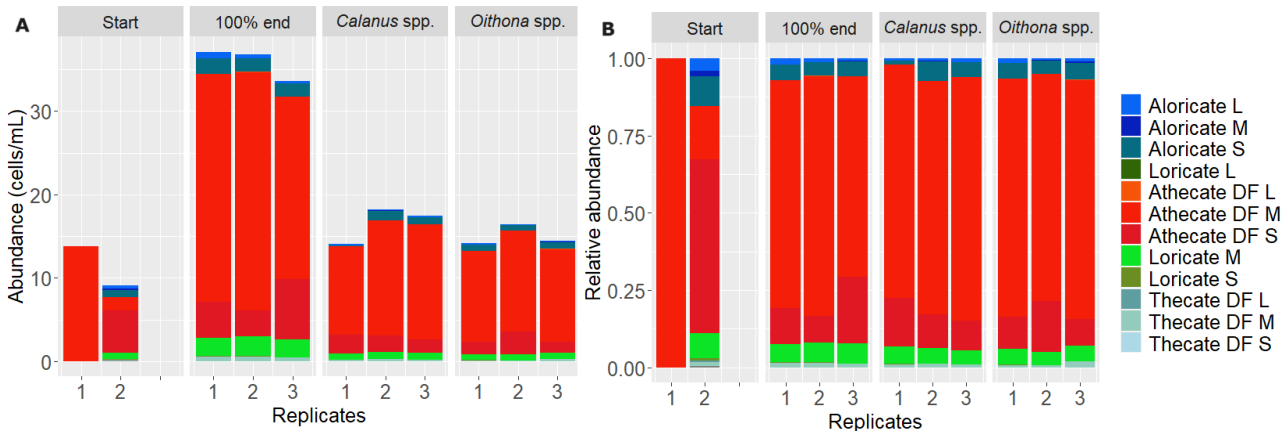


Figure 25: A) Absolute abundance [cells/mL] of microzooplankton for three replicates of; Start, 100% end, *Calanus* spp., and *Oithona* spp. at station P4 in August (cruise Q3). B) Relative abundance of microzooplankton for two replicates of Start, and three replicates of 100% end, *Calanus* spp., and *Oithona* spp. at station P4 in August (cruise Q3).

The phytoplankton Start abundance in August was 1.91 (SD 0.96) cells/mL and there were no significant differences with the 100% end at 2.66 (SD 0.51) cells/mL (*t*-test, p=0.40) (Figure 26A). There were no significant differences in *Calanus* spp. at 2.28 (SD 0.30) cells/mL and *Oithona* spp. at 2.39 (SD 4.5) cells/mL compared to 100% end (*t*-test, p=0.42 and 0.55, respectively). In all samples there were dominance of *Thalassiosira* spp., with high abundances of Silicoflagellates and Centric diatoms < 20 µm. In *Calanus* spp. and *Oithona* spp. there were higher abundances of Flagellates compared to Start and 100% end (Figure 26B).

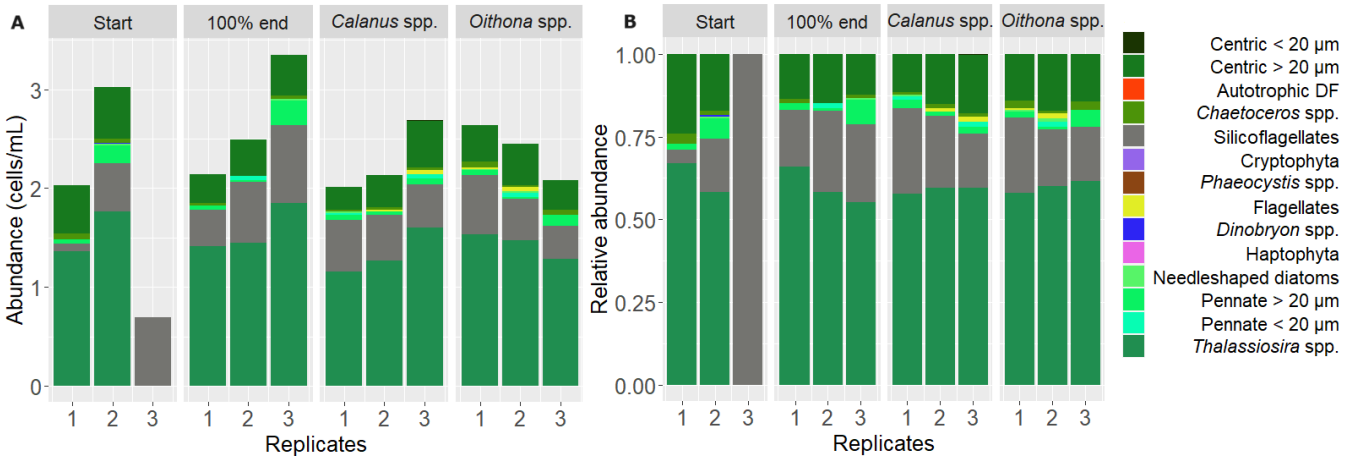


Figure 26: A) Absolute abundance [cells/mL] of phytoplankton for three replicates of; Start, 100% end, *Calanus* spp., and *Oithona* spp. at station P4 in August (cruise Q3). B) Relative abundance of phytoplankton for three replicates of Start, 100% end, *Calanus* spp.. and *Oithona* spp. at Station P4 in August (Q3).

The Start abundance for microzooplankton in December was 0.74 (SD 0.58) cells/mL. There was a non significant increase in the abundance of 100% end at 2.6 (SD 1.8) cells/mL) compared to 100% end (*t*-test, p=0.29) (Figure 27A). There were no

significant differences in *Calanus* spp. at 1.9 (SD 0.21) cells/mL, and *Oithona* spp. 2.1 (SD 0.60) cells/mL compared to 100% end (*t*-test, *p*=0.64 and 0.75, respectively). For Start the most abundant group was Athecate DF M, (20-50 µm), while for 100% end, *Calanus* spp. and *Oithona* spp. the most abundant group was Athecate DF S (<20 µm), with *Gymnodinium* spp. in different size classes being the most dominant species for all samples (Figure 27B).

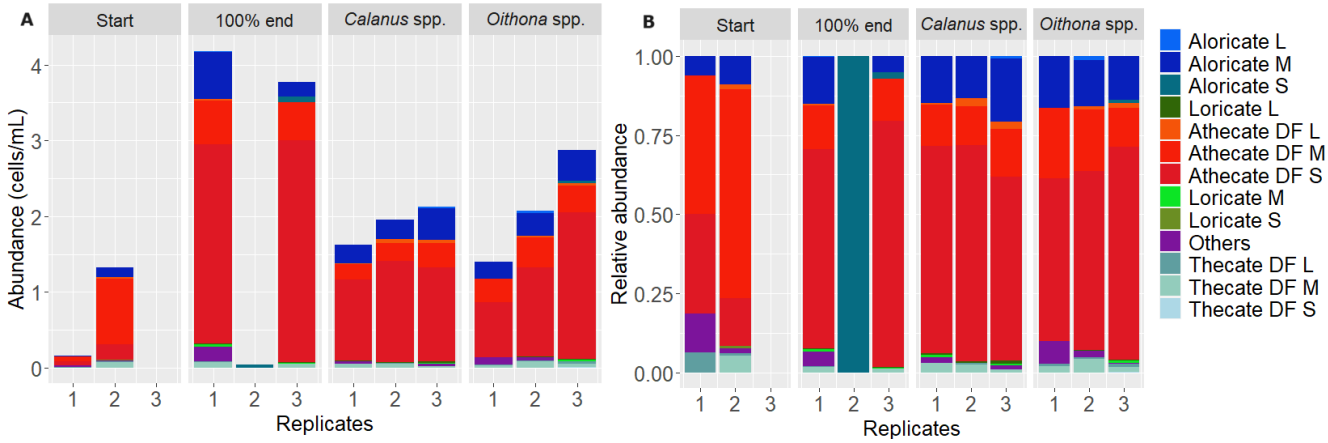


Figure 27: A) Absolute abundance [cells/mL] of microzooplankton for three replicates of; Start, 100% end, *Calanus* spp., and *Oithona* spp. at station P4 in December (cruise Q4). B) Relative abundance of microzooplankton for three replicates of Start, 100% end, *Calanus* spp., and Oithona spp. at station P4 in December (cruise Q4).

In December the Start abundance of phytoplankton was 0.085 (SD 0.01) cells/mL, and there were no significant increase in the 100% end at 0.21 (SD 0.21) cells/mL compared to Start (*t*-test, *p*=0.47) (Figure 28A). There were no significant differences in *Calanus* spp. at 0.067 (SD 0.021) cells/mL, and *Oithona* spp. at 0.11 (SD 0.07) cells/mL compared to 100% end (*t*-test, *p*=0.42 and 0.55, respectively). Start had dominance of *Thalassiosira* spp., while in 100% end, *Calanus* spp. and *Oithona* spp. there was dominance of Cryptophyta and 'Flagellates' (<5 µm). In *Oithona* spp. there was higher abundance of Pennate diatoms > 20 µm than for 100% end (Figure 28B).

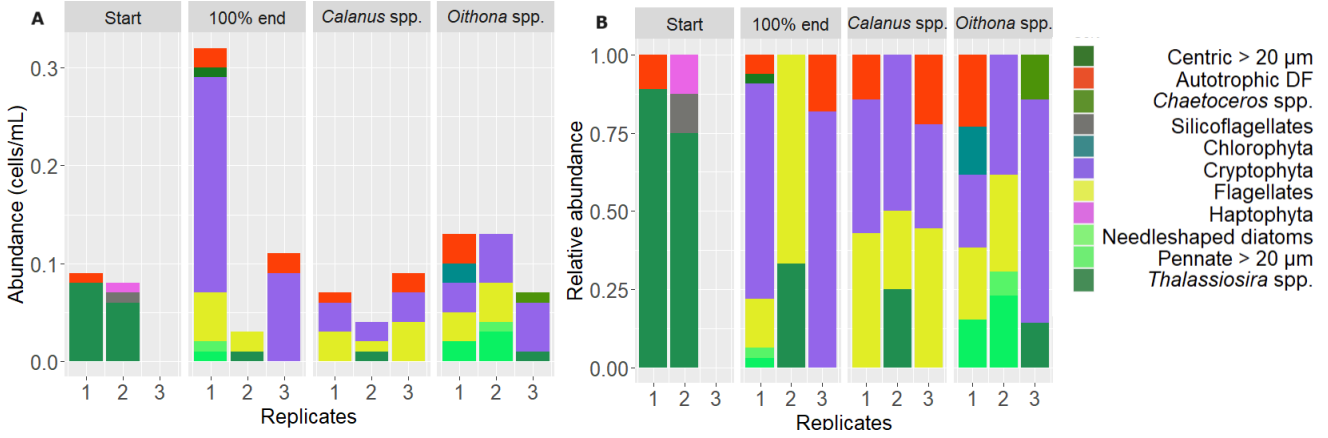


Figure 28: A) Absolute abundance [cells/mL] of phytoplankton for three replicates of; Start, 100% end, *Calanus* spp., and *Oithona* spp. at station P4 in December (cruise Q4). B) Relative abundance of phytoplankton for three replicates of Start, 100% end, *Calanus* spp., and *Oithona* spp. at station P4 in December (cruise Q4).

3.2.3 Station P1

Microzooplankton had the highest abundance in May with a decrease in abundance for December (*t*-test, $p<0.05$). Phytoplankton had the highest abundance in May, with a decrease in abundance in December (*t*-test, $p<0.05$).

In May the Start abundance was 31.6 (SD 9.4) cells/mL, there was no significant decrease for the 100% end at 14.3 (SD 2.2) cells/mL (*t*-test, $p=0.12$) (Figure 29A). There were no significant differences in *Calanus* spp. at 12.6 (SD 2.2) cells/mL, and *Oithona* spp. at 16.2 (SD 6.0) cells/mL compared to 100% end (*t*-test, $p=0.58$ and 0.70, respectively). For all samples Athecate DF S (<20 µm) were dominant, with *Gymnodinium* spp. being the most abundant species. There was less abundance of Thecate DF M and Aloricate L in 100%, *Calanus* spp., and *Oithona* spp. compared to 100% end (Figure 29B).

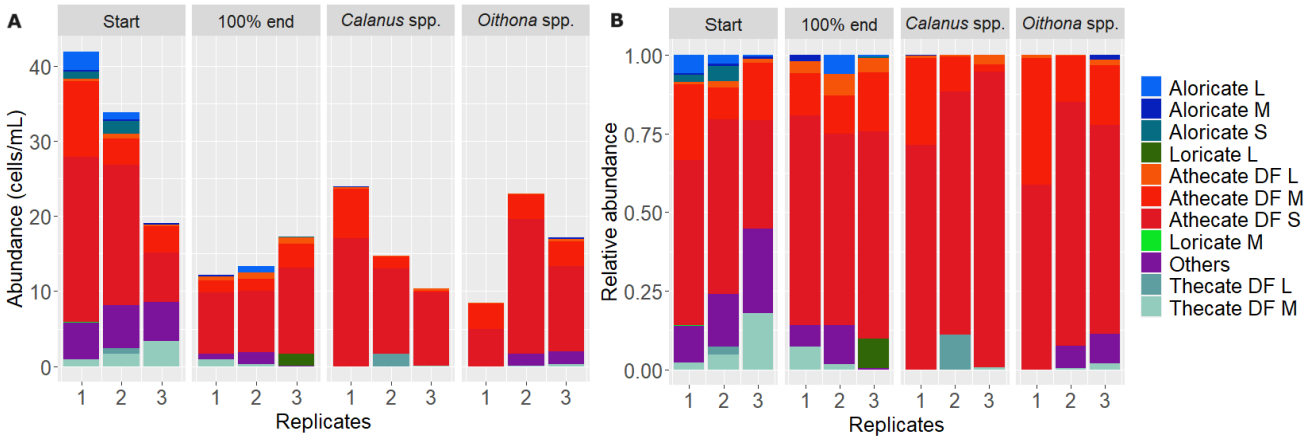


Figure 29: A) Absolute abundance [cells/mL] of microzooplankton for three replicates of; Start, 100% end, *Calanus* spp., and *Oithona* spp. at station P1 in May (cruise Q2). B) Relative abundance of microzooplankton for three replicates of Start, 100% end, *Calanus* spp., and *Oithona* spp. at station P1 in May (cruise Q2).

The Start phytoplankton abundance in May was 1016 (SD 106) cells/mL. There was a decrease in abundance for 100% end, with an abundance of 589 (SD 64) cells/mL compared to Start (*t*-test, $p<0.05$) (Figure 30A). Mostly due to less abundance of 'Flagellates' (<5 µm). Between 100% end and *Calanus* spp. at 454 (SD 286) cells/mL there were no significant differences, however, *Calanus* spp. had higher abundance of *Phaeocystis* spp. *Oithona* spp. at 1096 (SD 173) cells/mL had an observed increase in abundance compared to 100% end (*t*-test, $p<0.05$), mostly due to increased abundance of *Chaetoceros* spp., and Centric diatoms < 20 µm. In all samples there were high abundances of *Chaetoceros* spp., Pennate diatoms <20 µm and *Thalassiosira* spp. (Figure 30B).

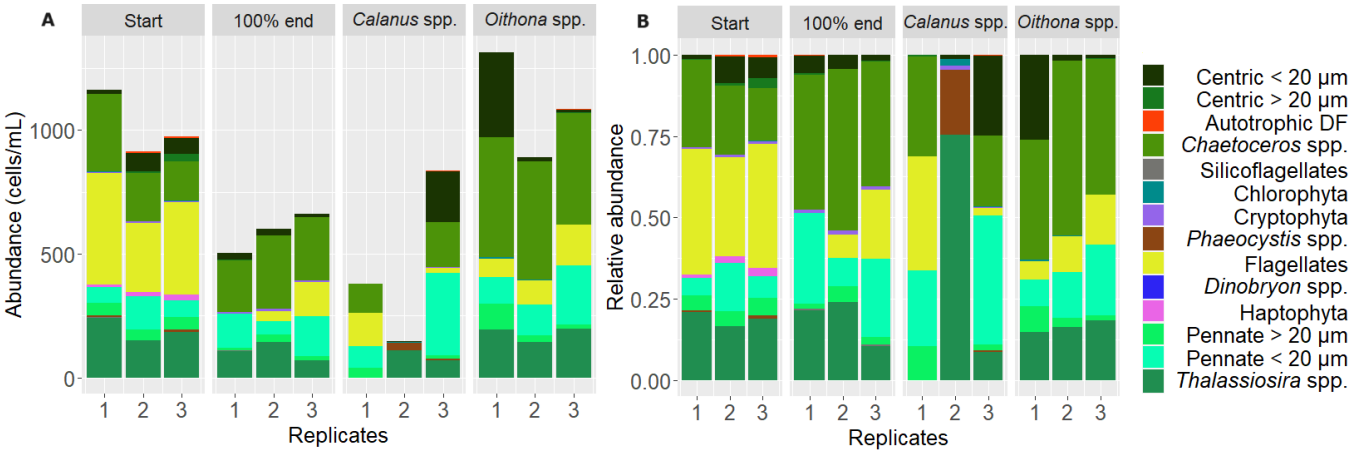


Figure 30: A) Absolute abundance [cells/mL] of phytoplankton for three replicates of; Start, 100% end, *Calanus* spp., and *Oithona* spp. at station P1 in May (cruise Q2). B) Relative abundance of phytoplankton for three replicates of Start, 100% end, *Calanus* spp., and *Oithona* spp. at station P1 in May (cruise Q2).

In December the Start microzooplankton abundance was 1.16 (SD 0.63) cells/mL (Figure 31A). There was an increase in abundance for 100% end, with an abundance of 4.47 (SD 0.89) cells/mL, compared to Start (*t*-test, $p<0.05$). The increase in 100% was mostly due to Athecate DF M (20-50 µm), with *Gymnodinium* spp. being the dominating species. In *Calanus* spp. at 3.48 (SD 0.38) cells/mL and *Oithona* spp. at 3.87 (SD 0.83) cells/mL compared to 100% end there were no significant differences (*t*-test, $p=0.25$ and 0.53, respectively). For all samples Athecate DF M was the most abundant group, with an increase in abundance for 100% end, *Calanus* spp., and *Oithona* spp. compared to Start (Figure 31B).

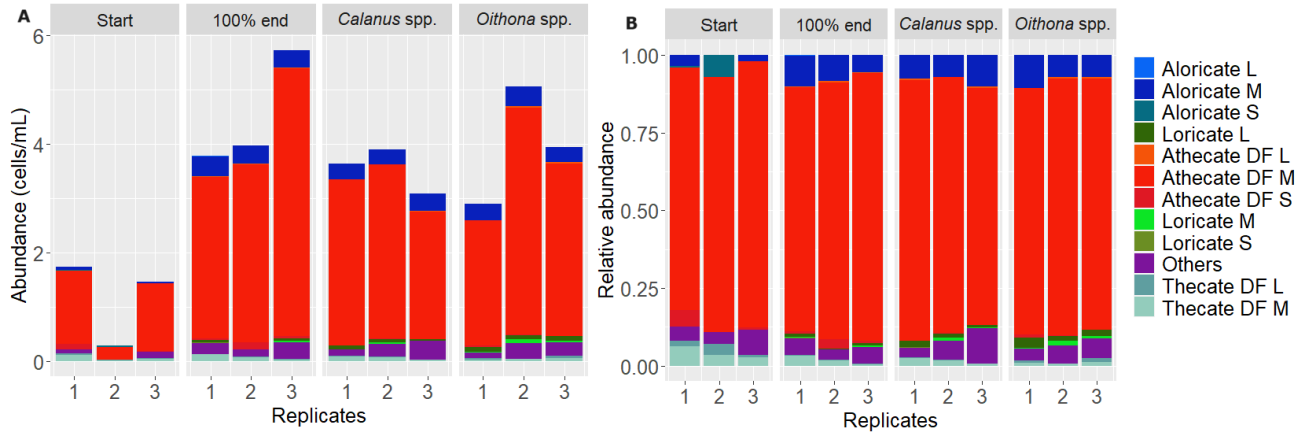


Figure 31: A) Absolute abundance [cells/mL] of microzooplankton for three replicates of; Start, 100% end, *Calanus* spp., and *Oithona* spp. at station P1 in December (cruise Q4). B) Relative abundance of microzooplankton for three replicates of Start, 100% end, *Calanus* spp., and *Oithona* spp. at station P1 in December (cruise Q4).

In December the Start abundance of phytoplankton was 0.022 (SD 0.011) cells/mL (Figure 32A). There was an increase in abundance for the 100% end at 1.0 (SD 0.18) cells/mL, compared to Start (*t*-test, $p<0.05$). Start had a dominance of *Thalassiosira* spp., while 100% had an increase in the abundance of Cryptophyta. In *Calanus* spp. at 0.99 (SD 0.50) cells/mL and *Oithona* spp. at 1.1 (SD 0.64) cells/mL there were no significant difference with 100% end (*t*-test, $p=0.97$ and 0.90, respectively). In 100%

end, *Calanus* spp., and *Oithona* spp. there were dominance of Cryptophyta, with *Leucocryptos marina* being the most abundant species (Figure 32B).

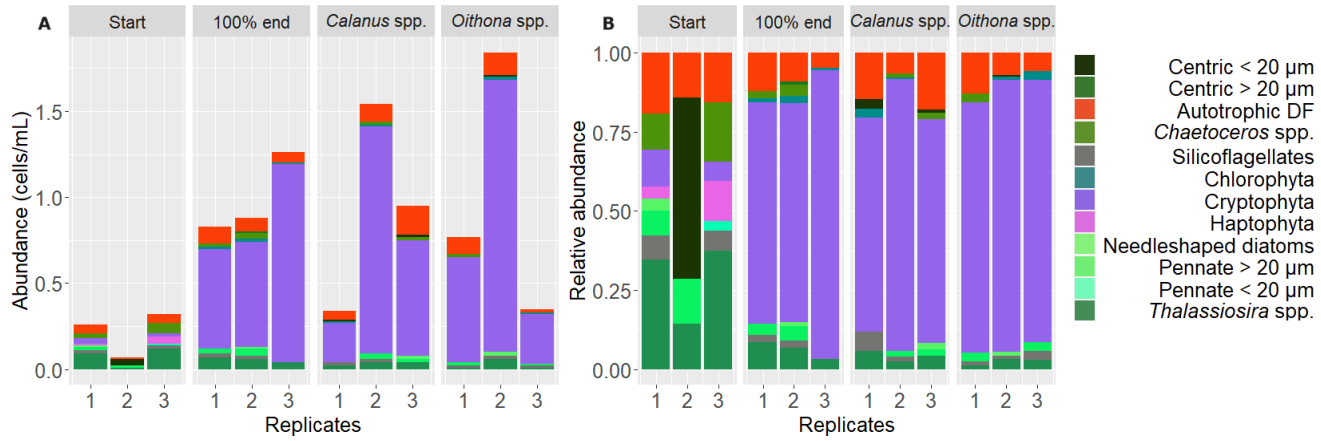


Figure 32: A) Absolute abundance [cells/mL] of phytoplankton for three replicates of; Start, 100% end, *Calanus* spp., and *Oithona* spp. at station P1 in December (cruise Q4). B) Relative abundance of microzooplankton for three replicates of Start, 100% end, *Calanus* spp., and *Oithona* spp. at station P1 in December (cruise Q4).

3.3 Growth rates for phytoplankton and microzooplankton

3.3.1 Station P7

In March (Q1), the highest growth rate for 100% end was 0.885 d^{-1} for Haptophyta and growth of phytoplankton was higher than growth of microzooplankton (*t*-test, $p<0.05$) (Table 5). Compared to the 100% end, the addition of *Calanus* spp. did not have significant effect on growth for phytoplankton and microzooplankton (*t*-test, p=0.77 and 0.44, respectively). There was however, higher growth of phytoplankton compared to microzooplankton (*t*-test, $p<0.05$), with the highest growth for Chlorophyta (0.588 d^{-1}). *Oithona* spp. was not significantly different from 100% end for growth of phytoplankton and microzooplankton (*t*-test, $p=0.77$ and 0.94, respectively). There was no significant difference in the growth of phytoplankton and microzooplankton (*t*-test, $p=0.16$). The mean growth of phytoplankton was higher in March than May, but the difference was not significant (*t*-test, $p=0.60$). There was no significant difference in the growth of microzooplankton from March to May (*t*-test, $p=0.86$).

The highest growth rate in May (Q2) for 100% end was 0.761 d^{-1} for Centric diatoms > 20 µm (Table 5), with no significant difference in growth rates between phytoplankton and microzooplankton (*t*-test, $p=0.063$). The treatment with added *Calanus* spp. was not significantly different from 100% end for growth of phytoplankton and microzooplankton (T-test, p=0.92 and 0.82, respectively). There was no significant difference in the growth of phytoplankton and microzooplankton (*t*-test, $p=0.49$). The addition of *Oithona* spp. was not significantly different from 100% end for growth of phytoplankton (*t*-test, $p=0.73$), or microzooplankton (*t*-test, $p=0.55$). The growth of phytoplankton and microzooplankton was not significantly different (*t*-test, $p=0.49$). There was no significant difference in the growth of phytoplankton from May to August (*t*-test, $p=0.61$). Nutrients did not lead to higher growth rates for phytoplankton or microzooplankton (*t*-test, $p=0.87$ and 0.81, respectively). The growth of microzooplankton increased from May to August (*t*-test, $p<0.05$), with high growth of Centric diatoms > 20 µm and *Thalassiosira* spp.

In August (Q3), the highest growth rate for 100% end was 1.24 d^{-1} for Centric diatoms > 20 µm, with no significant differences in growth of phytoplankton and microzooplankton (*t*-test, *p*=0.46) (Table 5). *Calanus* spp. was not significantly different from 100% end in growth of microzooplankton (*t*-test, *p*=0.093) or phytoplankton (*t*-test, *p*=0.60). Treatments with *Oithona* spp. did not have increased or decreased growth of phytoplankton or microzooplankton compared to 100% end (*t*-test, *p*=0.49 and 0.41, respectively). There were no significant differences in the growth rates of phytoplankton and microzooplankton in *Calanus* spp., and *Oithona* spp. (*t*-test, *p*=0.63 and 0.58, respectively). There were no increase in growth for phytoplankton or microzooplankton with addition of nutrients (*t*-test, *p*=0.50 and 0.16, respectively). Phytoplankton growth rates decreased from May to August, but it was not significant (*t*-test, *p*=0.39). Microzooplankton growth rates did not change significantly from August to December (*t*-test, *p*=0.26).

The highest growth rate in December (Q4) was for Autotrophic DF for 100% end and it was 0.461 d^{-1} (Table 5). There was less growth for phytoplankton compared to microzooplankton, but the difference was not significant (*t*-test, *p*=0.136). Phytoplankton and microzooplankton growth rates in *Calanus* spp. were not higher or lower than 100% end (*t*-test, *p*=0.51 and 0.51, respectively). In *Oithona* spp. phytoplankton growth rates were similar to the 100% end (*t*-test, *p*=0.92). The growth rates for microzooplankton were lower than the 100% end (*t*-test, *p*<0.05), mostly due to decreased growth of Thecate DF S and Aloricate S.There were no significant differences in the growth rates of phytoplankton and microzooplankton in *Calanus* spp. and *Oithona* spp. (*t*-test, *p*=0.16 and 0.96). Nutrient limitation did not increase the growth of phytoplankton or microzooplankton compared to the 100% end (*t*-test, *p*=0.88 and 0.90, respectively). From December to March the growth of phytoplankton was not significantly different (*t*-test, *p*=0.35), while for microzooplankton there was a decrease in growth (*t*-test, *p*<0.05).

Table 5: Growth rates (d^{-1}) for Cruises Q1 (March), Q2 (May), Q3 (August) and Q4 (December) for Station P7. Increasing orange color is negative growth rates and increasing blue color is positive growth rates. The symbol "+" means that there was no end abundance, but a start and and "#" indicate that there was no start abundance but an end abundance, but calculations were not possible.

	Growth rates (d^{-1})																	
	100% end				*Calanus* spp.				*Oithona* spp.				Nutrients					
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4		
"Flagellates"	0.12	-1.25	0.35	0.04	+	-1.35	0.29	0.07	+	-1.36	+	0.07	-1.35	+	+			
Autotrophic DF	0.12	-0.11	NA	0.46	0.13	-0.07	NA	0.35	0.09	-0.02	NA	0.64	-0.11	NA	0.43			
Centric diatoms < 20 µm	NA	0.20	NA	NA	NA	0.10	NA	NA	NA	0.16	#	#	0.25	#	#			
Centric diatoms > 20 µm	NA	0.76	1.24	NA	NA	0.69	0.69	#	NA	0.75	0.72	#	0.78	0.68	NA			
Pennate diatoms < 20 µm	NA	-0.01	+	NA	NA	-0.05	0.81	NA	NA	+	0.81	NA	-0.07	0.88	NA			
Pennate diatoms > 20 µm	0.39	0.53	0.39	0.37	0.39	0.34	0.16	0.39	0.37	0.28	-0.03	0.05	0.29	-0.04	0.39			
Needleshaped diatoms	NA	0.25	0.11	+	NA	0.19	0	0.59	NA	0.17	0.11	0.43	0.20	0.11	+			
Chaetoceros spp.	0.44	0.70	#	+	0.40	0.61	#	0.39	0.41	0.26	#	+	0.64	#	+			
Thalassiosira spp.	0.43	0.22	0.80	-0.06	0.56	0.16	0.82	-0.03	0.53	0.14	0.82	0.06	0.20	0.82	0.12			
Chlorophyta	0.63	-0.11	NA	-0.28	0.59	-0.05	NA	-0.31	0.66	-0.05	NA	-0.32	-0.04	NA	-0.21			
Cryptophyta	-0.25	0.23	NA	0.38	-0.23	0.26	NA	0.39	-0.27	0.23	NA	0.26	0.22	NA	0.31			
Haptophyta	0.89	0.41	NA	#	0.55	0.46	NA	#	0.58	0.37	NA	#	0.37	NA	#			
Phaeocystis spp.	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA			
Dinobryon spp.	#	0	NA	NA	NA	0.01	NA	NA	NA	0	NA	NA	+	NA	NA			
Silicoflagellates	NA	0.32	-0.78	NA	#	0.39	-0.70	#	NA	0.36	-0.77	#	0.33	-0.78	NA			
Others	-0.43	-0.15	NA	0.23	-0.73	-0.17	NA	0.13	-0.40	-0.31	NA	-0.25	-0.41	NA	0.15			
Athecate DF M	0.04	0.04	0.15	0.16	-0.087	0.04	0.03	0.34	0	-0.12	0.20	0.03	0.03	-0.21	0.03			
Athecate DF S	-0.07	0.01	0.27	0.40	-0.14	0	0.07	0.30	-0.10	0.04	0.22	0.09	-0.03	0	0.09			
Ahecate DF L	0.16	-0.49	0.51	0.19	0.13	-0.40	0.34	0.17	+	-0.46	0.65	0.01	-1.04	0.29	0.01			
Thecate DF M	0.014	0.02	0.46	-0.01	-0.29	0.06	0.30	0.21	-0.08	-0.24	0.45	-0.14	0.06	0.18	-0.14			
Thecate DF S	NA	NA	+	NA	NA	NA	+	NA	NA	NA	+	NA	NA	+	NA			
Aloricate L	NA	-0.16	0.75	#	NA	0	0.13	#	NA	0.06	0.42	NA	0.15	0.23	#			
Aloricate M	-0.13	-0.26	0.03	0.11	-0.15	-0.59	-0.25	0.33	-0.03	-0.32	-0.30	0	-0.09	0.01	0.33			
Aloricate S	-0.39	-0.08	0.39	0.33	-0.85	-0.35	0.01	0.22	-0.70	0	-0.12	-0.04	-0.17	0.15	0.15			
Loricate L	0	-0.03	0.18	0.24	0	+	+	0.59	0.57	0.12	0.18	0.06	-0.03	+	0.30			
Loricate M	-0.19	0.12	0.43	0.44	-0.12	-0.26	0.10	0.46	+	0.05	0.23	0.33	-0.13	0.11	0.57			
Loricate S	NA	-0.31	0.44	NA	NA	+	0.08	NA	NA	+	0.42	NA	+	0.16	NA			

3.3.2 Station P4

In March the experiment was only done for the 100% end, with the highest growth being for *Chaetoceros* spp. and it was 0.445 d^{-1} (Table 6). The growth rates for phytoplankton were higher than for microzooplankton, but the difference was not significant (*t*-test, $p=0.068$). There was a decrease in growth rates for phytoplankton and microzooplankton from March to May (*t*-test, $p<0.05$).

The highest growth rate for 100% end in May was for Silicoflagellates at 0.747 d^{-1}, and the growth rates of phytoplankton were higher than for microzooplankton (*t*-test, $p<0.05$). Adding *Calanus* spp. did not lead to any significant changes in growth rate for phytoplankton (*t*-test, $p=0.78$) and microzooplankton (*t*-test, $p=0.37$). There was not any difference in the growth rates of phytoplankton and microzooplankton (*t*-test, $p=0.15$). In *Oithona* spp. there was no significant increase or decrease in growth of phytoplankton (*t*-test, $p=0.52$) and microzooplankton (*t*-test, $p=0.41$) compared to 100% end. The growth rates of phytoplankton were higher than the growth rates of microzooplankton (*t*-test, $p<0.05$), mostly due to decreased growth of Athecate DF M and S. There was no significant increase in the growth of phytoplankton (*t*-test, $p=0.19$) and microzooplankton (*t*-test, $p=0.26$) with addition of nutrients. Phytoplankton and microzooplankton growth rates increased from May to August (*t*-test, $p<0.05$).

In August, the highest growth rate was for Loricate M for 100% end, and it was 1.09 d^{-1} (Table 6). The growth of microzooplankton was higher than phytoplankton (*t*-test, $p<0.05$). Addition of *Calanus* spp. did not lead to significant changes in growth rates of phytoplankton (*t*-test, $p=0.52$) and microzooplankton (*t*-test, $p=0.99$), compared to 100% end. Oithona spp. had no significant change in growth rates for phytoplankton (*t*-test, $p=0.57$). Microzooplankton with added *Oithona* spp. had decreased growth compared to 100% end (*t*-test, $p<0.05$), mostly due to decreased growth of Aloricate S and Loricate M. Phytoplankton and microzooplankton growth rates did not differ significantly in *Calanus* spp. (*t*-test, $p=0.43$), and *Oithona* spp. (*t*-test, $p=0.64$). Addition of nutrients did not cause increased growth in phytoplankton (*t*-test, $p=0.77$) and it led to a decrease in growth for microzooplankton (*t*-test, $p<0.05$). From August to December there no significant change in the growth rate of phytoplankton (*t*-test, $p=0.63$), and there was a decrease in the growth rate of microzooplankton (*t*-test, $p<0.05$).

The highest growth rate in December for 100% end was for Athecate DF S at 0.951 d^{-1}, with no significant differences in growth between phytoplankton and microzooplankton (*t*-test, $p=0.34$) (Table 6). In *Calanus* spp. there was no significant change in growth rate for phytoplankton (*t*-test, $p=0.94$), and microzooplankton (*t*-test, $p=085$), compared to 100% end. Addition of *Oithona* spp. did not lead to significant changes in growth rates for phytoplankton (*t*-test, $p=0.97$) and microzooplankton (*t*-test, $p=0.47$).There was no significant change in the growth of phytoplankton and microzooplankton in *Calanus* spp. (*t*-test, $p=0.49$) and *Oithona* spp. (*t*-test, $p=0.39$). Addition of nutrients did not lead to significant growth for phytoplankton (*t*-test, $p=0.34$) and microzooplankton (*t*-test, $p=0.63$). From December to March there was no significant change in growth rates of phytoplankton (*t*-test, $p=0.26$) and microzooplankton (*t*-test, $p=0.47$).

Table 6: Growth rates (d^{-1}) for Cruises Q1, Q2, Q3 and Q4 for Station P4. Increasing orange color is negative growth rates and increasing blue growth rates are positive growth rates. The symbol "+" means that there was no end abundance, but a start and "#" indicate that there was no start abundance but an end abundance, but calculations were not possible.

	Growth rates (d^{-1})															
	100% end				*Calanus* spp.				*Oithona* spp.				Nutrients			
	Q1	Q2	Q3	Q4	Q2	Q3	Q4		Q2	Q3	Q4		Q2	Q3	Q4	
"Flagellates"	0.16	-0.95	NA	#	-1.62	#	#		-0.88	#	#		-1.14	NA	#	
Autotrophic DF	NA	-1.0	NA	0.49	-0.62	NA	0.39		-0.73	NA	0.30		-0.86	NA	0.49	
Centric diatoms < 20 µm	0.39	-0.30	NA	NA	-0.55	#	NA		-0.60	NA	NA		-0.48	NA	NA	
Centric diatoms > 20 µm	NA	0.47	0.39	#	0.99	0.40	NA		0.47	0.36	NA		1.61	0.48	NA	
Pennate diatoms < 20 µm	#	0.05	#	NA	-0.10	#	NA		-0.09	#	NA		0.07	#	NA	
Pennate diatoms > 20 µm	0.32	-0.09	0.32	#	-0.21	0.32	NA		-0.14	0.34	#		-0.03	+	#	
Needleshaped diatoms	#	-0.24	0.40	#	-0.22	0.40	NA		+	0.35	#		-0.13	+	NA	
Chaetoceros spp.	NA	-0.18	0.45	NA	-0.23	0.48	NA		-0.28	0.43	#		0.12	0.49	NA	
Thalassiosira spp.	0.30	-0.17	0.34	+	-0.25	0.95	0.08		-0.08	0.35	0.08		-0.16	0.36	+	
Chlorophyta	0.34	-0.46	NA	NA	-0.47	NA	NA		-0.48	NA	#		-0.40	NA	#	
Cryptophyta	-0.13	-0.26	NA	#	-0.12	NA	#		-0.25	NA	#		-0.18	0	+	
Haptophyta	0.18	-0.28	NA	NA	-0.13	NA	+		0.07	NA	+		-0.20	0	+	
Phaeocystis spp.	NA	NA	NA	NA	NA	NA	NA		NA	NA	NA		NA	NA	NA	
Dinobryon spp.	NA	+	+	NA	0.19	+	NA		+	+	NA		0.25	+	NA	
Silicoflagellates	+	+	0.43	NA	+	0.16	NA		0.73	0.42	NA		0.73	0.47	NA	
Others	-0.14	-0.18	NA	0.70	-0.36	NA	0.74		-0.19	NA	0.69		-0.18	NA	0.77	
Athecate DF M	0.25	-0.60	0.79	0.15	-0.51	4.89	-0.09		-0.75	0.39	0.05		-0.86	+	-0.05	
Athecate DF S	-0.37	-0.38	0.29	0.95	-0.32	0	1.09		-0.51	0	1.08		-0.42	NA	1.02	
Athecate DF L	NA	-0.59	NA	#	-0.45	1.3	#		-0.83	0.18	#		-0.30	+	#	
Thecate DF M	0.73	-0.28	1.23	0.25	0.46	0.70	0.19		0.47	0.62	0.29		0.71	+	0.29	
Thecate DF S	NA	NA	NA	NA	NA	NA	NA		NA	NA	NA		NA	NA	NA	
Aloricate L	#	-0.38	0.67	#	-0.05	0.13	#		NA	0.08	#		-0.44	+	#	
Aloricate M	-0.23	-0.77	-0.05	0.82	-0.77	-0.05	1.17		-1.01	-0.09	1.15		-0.66	+	1.16	
Aloricate S	-0.23	-0.91	1.07	#	-0.39	0.09	NA		-0.64	0.02	#		-1.06	+	#	
Loricate L	#	#	NA	#	#	NA	#		#	NA	#		NA	NA	#	
Loricate M	-0.18	-0.92	1.09	-0.08	-0.54	0.61	-0.27		-0.58	0.54	0.18		-0.31	+	0.11	
Loricate S	NA	-0.05	0.80	+	-0.30	0.33	NA		-0.40	0.44	NA		-0.03	+	NA	

3.3.3 Station P1

For station P1 there was only data from May and December. In May the highest growth rate for the 100% end was for Chlorophyta at 0.65 d^{-1} (Table 7). In *Calanus* spp. there were no significant changes in the grow rates for phytoplankton (*t*-test, p=0.23) and microzooplankton (*t*-test, p=0.30). With addition of *Oithona* spp. there were no significant differences in the growth of phytoplankton (*t*-test, p=0.19) and microzooplankton (*t*-test, p=0.88) compared to 100% end. There was no significant change in the growth rates for phytoplankton and microzooplankton in the 100% end (*t*-test, p=0.14), *Calanus* spp. (*t*-test, p=0.58) and *Oithona* spp. (*t*-test, p=0.80). Addition of nutrients did not lead to increased growth of phytoplankton (*t*-test, p=0.24) and microzooplankton (*t*-test, p=0.48). From May to December there was a decrease in growth of phytoplankton (*t*-test, $p<0.05$) and microzooplankton (*t*-test, $p<0.05$).

In December, the highest growth in 100% end was for Cryptophyta at 1.75 d^{-1} (Table 7). In *Calanus* spp. there was no significant difference in growth rates for phytoplankton (*t*-test, p=0.49) and microzooplankton (*t*-test, p=0.64), compared to 100% end. Phytoplankton and microzooplankton growth rates were not significant different from 100% end in treatments with added *Oithona* spp. (*t*-test, p=0.19 and 0.88, respectively). There was no significant changes in the growth rates for phytoplankton and microzooplankton in 100% end (*t*-test, p=0.28), *Calanus* spp. (*t*-test, p=0.18) and *Oithona* spp. (*t*-test, p=0.36). Addition of nutrients did not lead to increased growth rates for phytoplankton (*t*-test, p=0.31) and microzooplankton (*t*-test, p=0.81).

Table 7: Growth rates for Cruises Q2 and Q4 for Station P1. Increasing orange color is negative growth rates and increasing blue growth rates are positive growth rates. The symbol "+" means that there was no end abundance, but a start and "#" indicate that there was no start abundance but an end abundance, but calculations were not possible.

Growth rates (d^{-1})	100 %		*Calanus* spp.		*Oithona* spp.		Nutrients	
	Q2	Q4	Q2	Q4	Q2	Q4	Q2	Q4
"Flagellates"	-1.48	NA	-1.50	NA	-1.57	NA	-1.5	NA
Autotrophic DF	-0.47	0.35	-0.54	0.44	-0.36	0.23	-0.51	0.16
Centric diatoms < 20 µm	-0.88	+	0.35	-0.09	-0.44	-0.04	-0.51	0.01
Centric diatoms > 20 µm	-1.05	#	-1.05	NA	-1.02	NA	-1.06	NA
Pennate diatoms < 20 µm	-1.73	NA	1.10	NA	-1.92	NA	0.30	NA
Pennate diatoms > 20 µm	-0.57	0.38	-0.63	0.28	-0.22	0.11	-0.60	0.21
Needleshaped diatoms	NA	-0.04	NA	0.28	NA	0.28	NA	0.17
Chaetoceros spp.	0.07	0.02	-0.06	-0.03	0.25	0.02	0.59	+
Thalassiosira spp.	-0.22	0.63	-0.16	0.70	0.74	0.76	-0.17	0.69
Chlorophyta	0.65	#	0.57	#	0.45	#	0.56	#
Cryptophyta	-0.03	1.75	-0.15	1.64	-0.36	1.69	-0.37	1.2
Haptophyta	-0.03	0.42	-0.34	0.42	+	0.42	+	0.42
Phaeocystis spp.	+	NA	0.36	NA	+	NA	0.06	NA
Dinobryon spp.	+	NA	#	NA	+	NA	+	NA
Silicoflagellates	NA	-0.03	-0.32	0.13	+	-0.03	-0.47	0.08
Others	0.28	-0.19	+	0.52	0.05	0.48	-0.92	0.17
Athecate DF M	-0.57	0.62	-0.82	0.51	-0.29	0.55	-0.20	0.32
Athecate DF S	-0.31	0.21	-0.15	-0.19	-0.25	-0.20	-0.27	+
Athecate DF L	0.31	NA	-0.34	NA	-0.64	NA	-0.07	NA
Thecate DF M	-0.54	0.08	-0.60	-0.03	-0.94	-0.14	-1.59	0.14
Thecate DF S	NA	NA	NA	NA	NA	NA	NA	NA
Aloricate L	-0.57	#	+	NA	+	NA	-0.67	NA
Aloricate M	-0.05	1.12	-0.05	1.05	-0.05	1.08	-0.18	0.63
Aloricate S	NA	NA	NA	NA	NA	NA	NA	#
Loricate L	0.20	#	NA	#	NA	#	NA	#
Loricate M	NA	#	+	#	0.20	#	0.20	#
Loricate S	#	NA	NA	0	NA	NA	NA	NA

3.4 Grazing rates

3.4.1 Station P7

In March, the highest grazing rate observed for the 100% end was on *Chaetoceros* spp. at 0.76 d^{-1} (Table 8). *Calanus* spp. had higher mean grazing rate at 0.31 (SD 24) d^{-1} than 100% end at 0.22 (SD 0.24) d^{-1}, but this increase was not significant (*t*-test, p=0.55). This could be due to the observed higher grazing on *Thalassiosira* spp. with added *Calanus* spp. In the treatments with added *Oithona* spp., there was no significant change in grazing rate, compared to the 100% end (*t*-test, p=0.79). *Oithona* spp. had higher grazing rate with 0.29 (SD 0.22) d^{-1}, with higher grazing on *Thalassiosira* spp.

100% end in May had the observed highest grazing rate on Thalassiosira spp., with a grazing rate of 0.81 d^{-1}. There were no significant differences in the grazing rate between *Calanus* spp. with a grazing rate of 0.18 (SD 0.20) d^{-1}, and 100% with a grazing rate of 0.17 (SD 0.27) d^{-1} (*t*-test, p=0.39). With a shift to higher grazing on Pennate diatom > 20 µm and lower grazing on *Thalassiosira* spp., with added *Calanus* spp. In *Oithona* spp., with mean grazing rate of 0.16 d^{-1}, there were no significant differences in grazing rate compared to 100% end (*t*-test, p=0.73). With a shift to lower grazing rate on *Thalassiosira* spp, and higher grazing on Silicoflagellates. Addition of nutrients had a grazing rate of 0.14 (SD 0.19) d^{-1}, which was not significantly different from 100% end (*t*-test, p=0.99) (Table 8).

In August, the highest grazing rate for 100% end was on Pennate diatoms < 20 µm at 0.88 d^{-1}, with a grazing rate of 0.19 (SD 0.30) d^{-1}. With added *Calanus* spp. the mean grazing rate was 0.24 (SD 0.24) d^{-1}, and there were no significant changes in grazing rates compared to 100% end (*t*-test, p=0.93). There was a shift towards higher grazing on Silicoflagellates. Treatments with *Oithona* spp. had grazing rate of 0.35 (SD 0.29) d^{-1}, with no significant difference compared to the 100% end (*t*-test, p=0.95). *Oithona* spp. had higher rates on Centric diatoms > 20 µm. Addition of nutrients led to higher mean grazing rate at 0.35 (SD 29) d^{-1}, but this increase was not significant (*t*-test, p=0.60). With observed higher grazing on Pennate diatoms > 20 µm (Table 8).

The observed highest grazing rate in December for the 100% end was on Chlorophyta at 0.24 d^{-1} (Table 8). Treatments with *Calanus* spp. had a mean grazing rate of 0.03 (SD 0.19) d^{-1}, and was not significantly different to 100% with a mean grazing rate of 0.06 (SD 0.09) d^{-1} (*t*-test, p=0.59). With observed lower grazing on Chlorophyta, with added *Calanus* spp. With added Oithona spp., the mean grazing rate was 0.03 (0.06) d^{-1}, with no significant differences with the 100% end (*t*-test, p=0.60). With addition of *Oithona* spp., there was a shift towards lower grazing on Chlorophyta and *Thalassiosira* spp. Treatments with added nutrients were not significantly different from 100% end, but had higher grazing on Chlorophyta (*t*-test, p=0.80).

Table 8: Grazing rates (d^{-1}) for Cruises Q1, Q2, Q3 and Q4 for Station P7. Increasing blue color is positive grazing rates. The symbol "+" means that there was no end abundance, but a start and "#" indicate that there was no start abundance but an end abundance, but calculations were not possible. Red 0 are negative grazing rates that were set to 0, due to negative estimates.

Grazing rate (d^{-1})	100% end				*Calanus* spp.				*Oithona* spp.				Nutrients			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q2	Q3	Q4
Flagellates	0	0	0	0.02	+	0	0	0.15	+	0	+	0.19	0	+	+
Autotrophic DF	0.24	0.08	NA	0	0	0.27	NA	0	0.11	0.51	NA	0	0.08	NA	0
Centric diatoms < 20 µm	NA	0	NA	NA	NA	0	NA	NA	NA	0	#	#	0	#	#
Centric diatoms > 20 µm	NA	0.59	0	NA	NA	0.21	0.18	#	NA	0.54	0.32	#	0.70	0.10	NA
Pennate diatoms < 20 µm	NA	0	0.88	NA	NA	0	0.52	NA	NA	+	0.52	NA	0.23	0.88	NA
Pennate diatoms > 20 µm	0.44	0	0	0	0.44	0.44	0	0	0.36	0.11	0	0	0.15	0.53	0
Needleshaped diatoms	NA	0.45	0	+	NA	0.17	0	0	NA	0.05	0	0	0.18	0	+
Chaetoceros spp.	0.76	0	#	+	0.59	0	#	0	0.61	0	#	+	0	#	+
Thalassiosira spp.	0.06	0.81	0.23	0.14	0.67	0.48	0.32	0	0.53	0.38	0.34	0	0	0.32	0
Chlorophyta	0.34	0	NA	0.24	0.11	0	NA	0.09	0.48	0	NA	0.04	0	NA	0.57
Cryptophyta	0	0.03	NA	0	0.21	0.19	NA	0	0.03	0.04	NA	0	0.01	NA	0
Haptophyta	0	0.47	NA	#	0.48	0.46	NA	#	0	0.26	NA	#	0.26	NA	#
Phaeocystis spp.	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Silicoflagellates	NA	0.11	0.23	NA	NA	0.47	0.63	NA	NA	0.30	0.30	#	0.18	0.26	NA
Dinobryon spp.	#	0	NA	NA	NA	0.08	NA	NA	NA	0	NA	NA	+	NA	NA
Others	0.11	0	NA	0	0	0	NA	0	0.24	0	NA	0	0.21	NA	0

3.4.2 Station P4

In March, the highest grazing rate for the 100% end was for Centric diatoms < 20 µm at 0.34 d^{-1}, with grazing rate of 0.16 (SD 0.15) d^{-1} (Table *9*)

The highest observed grazing rate for the 100% end in May was on Autotrophic DF at 0.23 d^{-1}, and the mean grazing rate was 0.04 (SD 0.07) d^{-1} (Table *9*). Treatments with added *Calanus* spp. had grazing rate of 0.03 (SD 0.07) d^{-1}, with no significant difference to the 100% end (*t*-test, *p*=0.95). *Oithona* spp. did not have any significant differences in grazing rates, with grazing rate of 0.07 (SD 0.19) d^{-1}, compared to 100% end (*t*-test, *p*=0.59). However, there was observed increased grazing on Silicoflagellates. Treatments with added nutrients was not significantly different from 100% end (*t*-test, *p*=0.33).

In August, the highest grazing rate for the 100% was for Silicoflagellates at 0.45 d^{-1}, and the grazing rate was 0.36 (SD 0.11) d^{-1}.Treatments with added *Calanus* spp. had mean grazing rate of 0.31 (SD 0.20) d^{-1}, and was not statistically significant from 100% end (*t*-test, *p*=0.79). With addition of *Oithona* spp., the mean grazing rate was 0.28 (SD 0.11) d^{-1}, with no significant difference compared to the 100% end (*t*-test, *p*=0.85). Treatments with added nutrients were not significantly different from the 100% end (*t*-test, *p*=0.49).

December had the observed highest grazing rate in 100% end on 'Others' at 0.33 d^{-1}, and the grazing rate in 100% end was 0.17 (SD 0.17) d^{-1}.Treatments with added *Calanus* spp. had grazing rate of 0.27 (SD 0.21) d^{-1}, with no significant difference compared to 100% end (*t*-test, *p*=0.51). *Oithona* spp. had a mean grazing rate of 0.15 (SD 0.15) d^{-1}, and there was no significant difference to 100% end (*t*-test, *p*=0.93). Both *Calanus* spp., and *Oithona* spp. had a higher grazing rates on *Thalassiosira* spp. There was no significant difference in treatments with added nutrients compared to 100% end (*t*-test, *p*=0.93).

Table 9: Grazing rates (d^{-1}) for Cruises Q1 (March), Q2 (May), Q3 (August) and Q4 (December) for Station P4. Increasing blue color is positive grazing rates. The symbol "+" means that there was no end abundance, but a start and "#" indicate that there was no start abundance but an end abundance, but calculations were not possible. Red 0 are negative grazing rates that were set to 0, due to negative estimates.

Grazing rate (d^{-1})

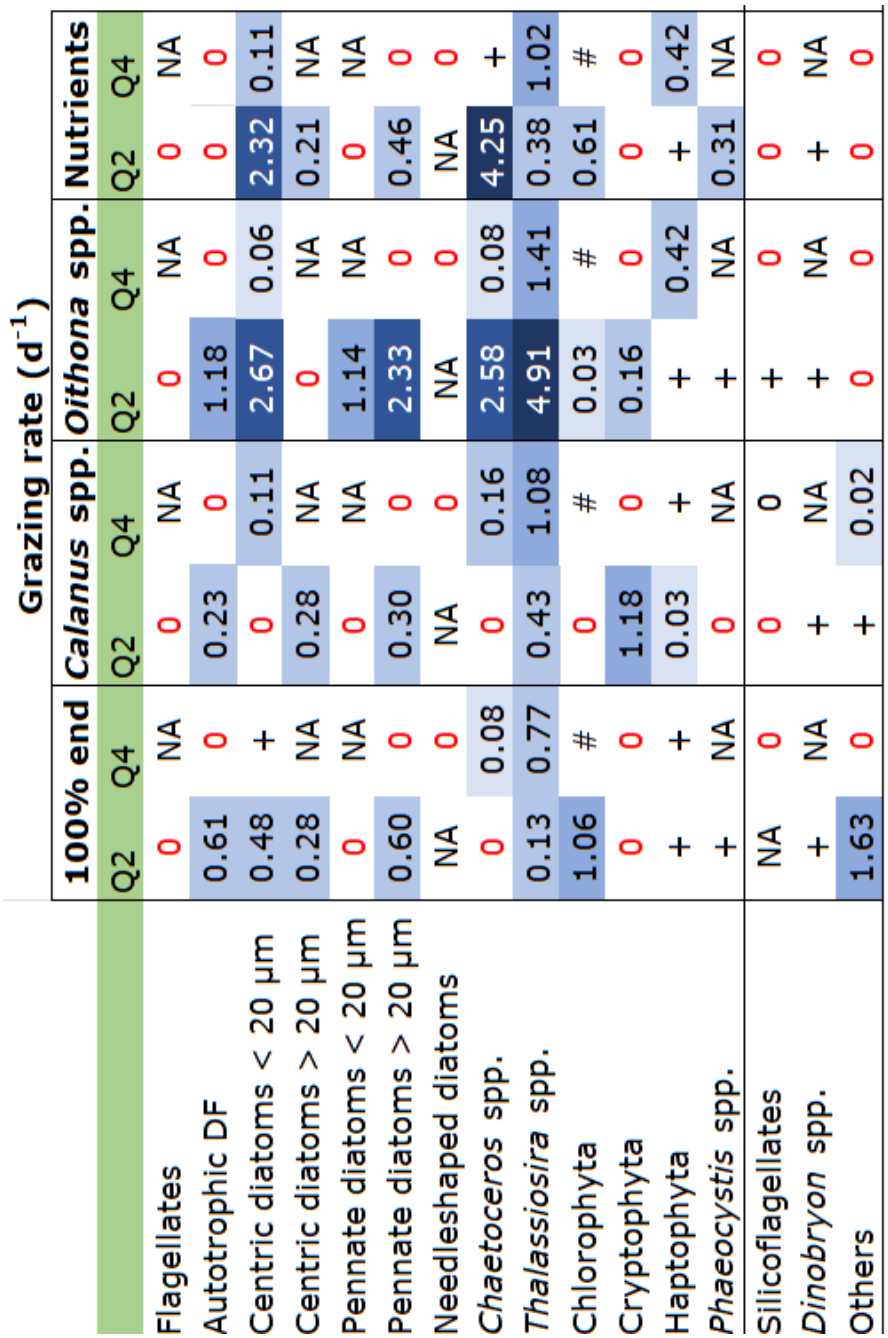
	100% end				*Calanus* spp.				*Oithona* spp.				Nutrients			
	Q1	Q2	Q3	Q4	Q2	Q3	Q4		Q2	Q3	Q4		Q2	Q3	Q4	
Flagellates	0.03	0	NA	#	0	#	#		0	#	#		0	NA	#	
Autotrophic DF	NA	0.23	NA	0	0	NA	0		0	NA	0		0	NA	0.49	
Centric diatoms < 20 µm	0.34	0	NA	NA	0	#	NA		0	NA	NA		0	NA	NA	
Centric diatoms > 20 µm	NA	0.10	0.37	#	0	0.42	NA		0	0.36	NA		0	0.79	NA	
Pennate diatoms < 20 µm	NA	0	#	NA	0.14	#	NA		0.18	#	NA		0	#	NA	
Pennate diatoms > 20 µm	0.32	0	0.43	#	0.03	0.43	NA		0	0.55	#		0	+	#	
Needleshaped diatoms	#	0	0.33	#	0.22	0.33	+		+	0.10	0		0.66	+	+	
Chaetoceros spp.	NA	0	0.43	NA	0	0.60	NA		0	0.35	#		0	0.68	NA	
Thalassiosira spp.	0.26	0	0.14	+	0.09	0	0.28		0	0.20	0.28		0	0.22	+	
Chlorophyta	0.34	0	NA	NA	0	NA	NA		0	NA	#		0	NA	#	
Cryptophyta	0	0.04	NA	#	0	NA	#		0	NA	#		0	NA	#	
Haptophyta	0	0	NA	+	0	NA	+		0	NA	+		0	NA	+	
Phaeocystis spp.	NA	NA	NA	NA	NA	NA	NA		NA	NA	NA		NA	NA	NA	
Silicoflagellates	#	+	0.45	NA	+	0.10	NA		0.68	0.39	NA		0.68	0.68	NA	
Dinobryon spp.	NA	+	+	NA	0	+	NA		+	+	NA		0	+	NA	
Others	0	0.13	NA	0.33	0	NA	0.52		0.04	NA	0.31		0.10	NA	0.70	

3.4.3 Station P1

In May, the highest grazing rate for 100% end was for 'Others' at 1.63 d^{-1} (Table 10), with a mean grazing rate of 0.32 (SD 0.34) d^{-1}. In treatments with added *Calanus* spp. the mean grazing rate was 0.10 (SD 0.16) d^{-1}, with a non-significant decrease in grazing rate compared to 100% end (*t*-test, p=0.30). *Oithona* spp. had grazing rate of 0.04 (SD 0.07) d^{-1}, which was lower than 100% end, but the difference was not significant (*t*-test, p=0.11). There was a trend toward higher grazing on Cryptophyta with added *Calanus* spp. In *Oithona* spp., there was a trend toward higher grazing on *Thalassiosira* spp., *Chaetoceros* spp., and Centric diatoms < 20 µm. Addition of nutrients did not lead to any significant changes in grazing rates compared to 100% end (*t*-test, p=0.46).

December had the highest grazing rate in 100% end on *Thalassiosira* spp. at 0.766 d^{-1}, and the grazing rate in 100% end was 0.11 (SD 0.25) d^{-1} (Table 10). Addition of *Calanus* spp., had grazing rate of 0.15 (SD 0.33) d^{-1}, with no significant difference to 100% end (*t*-test, p=0.71). Treatments with added *Oithona* spp. had a mean grazing rate of 0.06 (SD 0.13) d^{-1}, with no significant difference compared to 100% end (*t*-test, p=0.68). In both *Calanus* spp., and *Oithona* spp. there were higher grazing on *Thalassiosira* spp. Addition of nutrients did not have any significant impact on the grazing rates compared to 100% end (*t*-test, p=0.83).

Table 10: Grazing rates (d^{-1}) for Cruises Q2 (May) and Q4 (December) for Station P1. Increasing blue color is positive grazing rates. The symbol "+" means that there was no end abundance, but a start and "#" indicate that there was no start abundance but an end abundance, but calculations were not possible. Red 0 are negative grazing rates that were set to 0, due to negative estimates.



Grazing rate (d^{-1})	100% end		*Calanus* spp.		*Oithona* spp.		Nutrients	
	Q2	Q4	Q2	Q4	Q2	Q4	Q2	Q4
Flagellates	0	NA	0	NA	0	NA	0	NA
Autotrophic DF	0.61	0	0.23	0	1.18	0	0	0
Centric diatoms < 20 µm	0.48	+	0	0.11	2.67	0.06	2.32	0.11
Centric diatoms > 20 µm	0.28	NA	0.28	NA	0	NA	0.21	NA
Pennate diatoms < 20 µm	0	NA	0	NA	1.14	NA	0	NA
Pennate diatoms > 20 µm	0.60	0	0.30	0	2.33	0	0.46	0
Needleshaped diatoms	NA	0	NA	0	NA	0	NA	0
Chaetoceros spp.	0	0.08	0	0.16	2.58	0.08	4.25	+
Thalassiosira spp.	0.13	0.77	0.43	1.08	4.91	1.41	0.38	1.02
Chlorophyta	1.06	#	0	#	0.03	#	0.61	#
Cryptophyta	0	0	1.18	0	0.16	0	0	0
Haptophyta	+	+	0.03	+	+	0.42	+	0.42
Phaeocystis spp.	+	NA	0	NA	+	NA	0.31	NA
Silicoflagellates	NA	0	0	0	+	0	0	0
Dinobryon spp.	+	NA	+	NA	+	NA	+	NA
Others	1.63	0	+	0.02	0	0	0	0

3.5 Growth and grazing rates (based on Chl *a* estimates)

At station P7, the highest growth rate in 100% end was found in March (at 0.46 d^{-1}), followed by December (0.16 d^{-1}), May (0.13 d^{-1}) and the lowest growth in August (-0.02 d^{-1}) (Table 11). The highest grazing rate was in March (0.48 d^{-1}), followed by December (0.24 d^{-1}), August (0.14 d^{-1}), and May (0.09 d^{-1}). Addition of *Oithona* spp., did not seem to impact the grazing rates, but there was observed higher grazing in March (0.51 d^{-1}). Treatments with added *Calanus* spp., did have observed higher growth rates, but there observed higher grazing in March (0.56 d^{-1}). Addition of nutrients did not lead to higher growth or grazing rates.

For station P4, the highest growth rate in 100% end was observed in August (1.02 d^{-1}), followed by March (0.44 d^{-1}), May (0.23 d^{-1}) and the lowest in December (0.19 d^{-1}). The only positive grazing rate was found in March (0.50 d^{-1}). Addition of *Oithona* spp. did not impact the growth rates, but led to higher grazing in August (0.13 d^{-1}). Treatments with added *Calanus* spp. had lower growth in May (0.15 d^{-1}), and higher grazing rates in May (0.12 d^{-1}) and August (0.13 d^{-1}). Addition of nutrients did not lead to higher growth, but there was observed higher grazing in May (0.26 d^{-1}) (Table 11).

For Station P1, there was only found positive growt in May, where the 100% end had growth rate 0.38 d^{-1}. Addition of *Calanus* spp. led to higher growth (0.66 d^{-1}), while *Oithona* spp., did not change the growth rate (0.38 d^{-1}). Addition of nutrients led to slightly higher growth (0.40 d^{-1}). No positive growth rates were observed in May or December for any of the treatments (Table 11).

Table 11: Growth and grazing rates for the Chl *a* measurements from Cruises Q2 (May) and Q4 (December) for Stations P1, P4 and P7. Increasing blue color is positive rates and the orange is negative growth rates. Red 0 are negative grazing rates that were set to 0, due to negative estimates.

Growth and grazing rates (d^{-1})

			100% end		*Oithona* spp.		*Calanus* spp.		Nutrients	
Cruise	Year	Station	Growth	Grazing	Growth	Grazing	Growth	Grazing	Growth	Grazing
Q2	2021	P1	0.38	0	0.66	0	0.38	0	0.40	0
Q4	2019	P1	0	0	0	0	0	0	0	0
Q2	2021	P4	0.23	0	0.22	0	0.15	0.12	0.18	0.26
Q3	2019	P4	1.02	0	1.0	0.13	1.0	0.13	0.98	0.04
Q4	2019	P4	0.19	0	0.19	0	0.19	0	0.19	0
Q1	2021	P4	0.44	0.50	NA	NA	NA	NA	NA	NA
Q2	2021	P7	0.13	0.09	0.13	0.07	0.13	0.09	0.13	0.07
Q3	2019	P7	-0.02	0.14	-0.05	0.01	-0.03	0.10	-0.04	0.06
Q4	2019	P7	0.16	0.24	0.16	0.24	0.16	0.24	0.13	0.06
Q1	2021	P7	0.46	0.48	0.47	0.51	0.48	0.56	NA	NA

3.6 Growth and grazing rates (based on total abundance)

3.6.1 Station P7

In March, the highest growth rate for heterotrophs were for 100% end at -0.19 d^{-1} and the lowest growth rate for added *Calanus* spp. at -0.31 d^{-1}. The highest growth rate for autotrophs was 0.12 for added *Oithona* spp. and the lowest growth rate for 100% end at 0.071 d^{-1}. There were no positive grazing rates (Table 12).

The highest growth rate in May for heterotrophs was -0.06 d^{-1} for 100% end and the lowest was for added *Oithona* spp. at -0.12 d^{-1}. For autotrophs the highest growth was -1.23 d^{-1} at 100% and the lowest was -1.33 d^{-1} for added *Calanus* spp. There were no positive grazing rates.

In August, the highest growth for heterotrophs for 100% end was 0.33 d^{-1} and the lowest was for added Nutrients at -0.23 d^{-1}. Autotrophs had the highest growth for added nutrients at 0.50 d^{-1} and the lowest for 100% at 0.48 d^{-1}. The highest grazing rate was 0.33 d^{-1} for added nutrients (Table 12).

The highest growth rate in December was observed at 0.41 d^{-1} for 100% end and the lowest was for added *Calanus* spp. at -0.27 d^{-1}. For autotrophs the highest growth was 0.04 d^{-1} for 100% end and the lowest growth was -1.84 d^{-1} for added *Calanus* spp. there were no positive grazing rates.

3.6.2 Station P4

In March, there were only data from 100% end with a growth rate for heterotrophs which was -0.25 d^{-1}, growth for autotrophs was -0.04 d^{-1} and the grazing was 0.06 d^{-1} (Table 12).

The highest growth in May for heterotrophs was in treatments with added *Calanus* spp. with -0.37 d^{-1} and the lowest was -0.47 d^{-1} for added *Oithona* spp. For autotrophs the highest growth was 100% end at -0.48 d^{-1} and the lowest was for added *Calanus* spp. with -0.58 d^{-1}. There were not any positive grazing rates for any of the treatments.

In August, the highest growth was for 100% end at 0.76 d^{-1} and the lowest was 0 d^{-1} for added Nutrients. Autotrophs had the highest growth for added nutrients at 0.39 d^{-1} and the lowest for 100% end at 0.36 d^{-1}. The highest grazing rate was found in added Nutrients treatment at 0.38 d^{-1}.

December had the highest growth for heterotrophs for added *Oithona* spp. at 0.64 d^{-1} and the lowest for 100% end at 0.26 d^{-1}. For the autotrophs the highest growth was at 0.80 d^{-1} for the added *Calanus* spp. treatment and the lowest growth was at 0.72 d^{-1} for *Oithona* spp. The highest grazing rate was for *Calanus* spp. at 0.75 d^{-1}.

3.6.3 Station P1

For Station P1 in May the growth rates were all negative with the highest growth rate for heterotrophs were found for added *Calanus* spp. at -0.35 d^{-1} and the lowest growth was for 100% end at -0.45 d^{-1}. For autotrophs the highest growth rate was for added *Oithona*

spp. at 0.04 d^{-1} and the lowest was for added Nutrients at -0.42 d^{-1}. The highest grazing was for *Calanus* spp. at 0.19 d^{-1} (Table 12).

In December, the highest growth rate for heterotrophs was in 100% end at 0.62 d^{-1} and the lowest was at -1.37 d^{-1} for added Nutrients. Autotrophs had the highest growth at 0.69 d^{-1} for 100% end and the lowest growth at 0.32 d^{-1} for added Nutrients. The highest grazing was for added Nutrients at 1.28 d^{-1}, which was the only positive grazing rate in December.

Table 12: Growth rates for heterotrophs and autotrophs and grazing rates for the total abundance for each station P1, P4 and P7 for the seasonal cruises Q1, Q2, Q3 and Q4. Increasing blue color is positive rates and the orange is negative growth rates. Red 0 are negative grazing rates that were set to 0, due to negative estimates.

			Growth and grazing rates (d^{-1})											
			100% end			*Oithona* spp.			*Calanus* spp.			Nutrients		
Cruise	Year	Station	Growth H	Growth	Grazing	Growth H	Growth A	Grazing	Growth H	Growth A	Grazing	Growth H	Growth A	Grazing
Q2	2021	P1	-0.45	-0.31	0	-0.42	0.04	0	-0.35	-0.39	0.19	-0.39	-0.42	0.02
Q4	2019	P1	0.62	0.69	0	0.56	0.60	0	0.51	0.60	0	-1.37	0.32	1.28
Q2	2021	P4	-0.46	-0.48	0	-0.47	-0.52	0	-0.37	-0.58	0	-0.46	-0.50	0
Q3	2019	P4	0.76	0.36	0.205	0.33	0.37	0.26	0.38	0.38	0.29	0	0.39	0.38
Q4	2019	P4	0.26	0.74	0.473	0.64	0.72	0.37	0.62	0.80	0.75	0.62	0.78	0.65
Q1	2021	P4	-0.25	-0.04	0.0564	NA	NA	NA	NA	NA	NA	NA	NA	NA
Q2	2021	P7	-0.06	-1.23	0	-0.12	-1.42	0	-0.10	-1.44	0	-0.10	-1.36	0
Q3	2019	P7	0.33	0.48	0.217	0.24	0.50	0.32	0.06	0.50	0.32	-0.23	0.50	0.33
Q4	2019	P7	0.42	0.04	0	0.09	-1.33	0	-0.27	-1.84	0	0.31	-1.66	0
Q1	2021	P7	-0.19	0.07	0	-0.25	0.12	0	-0.31	0.08	0	NA	NA	NA

3.7 Statistical analyses

3.7.1 Growth microzooplankton

The ANOVA done on the growth rates of the heterotrophs can be seen in Table 13. For microzooplankton there was a significant difference in growth between May and August for P4 and P7 (ANOVA, $p<0.05$). August and December were significantly different for P4 (ANOVA, $p<0.05$). Tukey's HSD showed that there were no significant differences in microzooplankton growth along the geographical gradient from station P7, P4 and P1 for all seasons (Table 14).

Table 13: The analysis of variance (ANOVA) results from microzooplantkon growth rates. The 100% end samples were compared for the different Seasons and Stations and for the different treatments. The Seasons and treatments with added Calanus spp., Oithona spp. and Nutrients were significantly different from the 100% end sample.

Variable	Df	Sum Sq	Mean Sq	F value	Pr (> F)
Season	3	5.535	1.845	28.540	3.90e-13 ***
Station	2	0.022	0.011	0.170	0.8437
Season:Station	4	0.514	0.129	1.989	0.1027
Residuals	92	5.947	0.065		

Table 14: Tukey's HSD test for interaction between the stations P1, P4 and P7, for heterotrophic growth rates. The Stations were not significantly different from each other.

Variables	Diff	Lwr	Upr	P adj
P4 – P1	-0.0316	-0.184	0.120	0.875
P7 – P1	-0.0299	-0.181	0.122	0.885
P7 – P4	0.00171	-0.123	0.126	0.999

3.7.2 Growth phytoplankton

The ANOVA for the growth rates of the phytoplankton can be seen in Table 15. There were statistically significant differences in growth rates between seasons, with March and May being statistically significant for P4. May and August had significant differences in phytoplankton growth rates for P4 and P7 (ANOVA, $p<0.05$). Overall there was a difference in growth rates for P1 and P7 and P4 and P7 for all seasons (Table 16). Tukey's HSD showed that in every season, the only significant difference between was between station P4 and P7 in August (ANOVA, $p<0.05$).

Table 15: The analysis of variance (ANOVA) results from phytoplankton growth rates. The 100% end samples were compared for the different Seasons and Stations. The different sorting groups, Seasons and Stations, as well as the interaction between Seasons and Stations were significantly different from each other.

Variable	Df	Sum Sq	Mean Sq	F value	Pr (>F)
Season	3	3.66	1.22	43.2	2e-16 ***
Station	2	1.02	0.509	18.0	3.05e-07 ***
Seasons:Stations	4	0.306	0.076	2.711	0.0354 *
Residuals	84	2.370	0.028		

Table 16: Tukey's HSD test for interaction between the stations P1, P4 and P7, for autotrophic growth rates. Stations P7 and P1, and P7 and P4 were significantly different from each other.

Station	Diff	Lwr	Upr	P adj
P4-P1	-0.0419	-0.146	0.0621	0.603
P7-P1	0.166	0.0625	0.269	0.000707 ***
P7-P4	0.208	0.121	0.294	0.0000005 ***

3.6.2 Grazing rates

The ANOVA for the grazing rates can be seen in Table 17. For the grazing rates the seasons and stations were significantly different from each other. Q1 and Q4 were the only two months that were significantly different (ANOVA, $p<0.05$), for all stations. For all seasons there was a significant difference between station P1 and P4 (Table 18).

Table 17: The analysis of variance (ANOVA) results from grazing rates. The 100% end samples were compared for the different Seasons and Stations. The different Seasons and Stations were significantly different from each other.

Variable	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Season	3	0.3017	0.1006	2.817	0.0440 *
Station	2	0.2950	0.1475	4.131	0.0194 *
Season:Station	4	0.0561	0.0140	0.393	0.8135
Residuals	84	2.9990	0.0357		

Table 18: Tukey's HSD test for interaction between the stations P1, P4 and P7, for grazing rates. Stations P4 and P1 were significantly different from each other.

Station	Diff	Lwr	Upr	P adj
P4-P1	-0.129	-0.246	-0.0124	0.0266 *
P7-P1	-0.0901	-0.206	0.0259	0.159
P7-P4	0.0392	-0.0581	0.136	0.603

3.7 Shannon Wiener diversity indices

The Shannon Wiener diversity index (H') shows that the most diverse Station was P7 in March (H'=2.13) and the least diverse was for P7 in August (H'=1.18). For Station P1, May was the most diverse cruise, for P4 it was in March and for P7 it was in May (Figure 33).

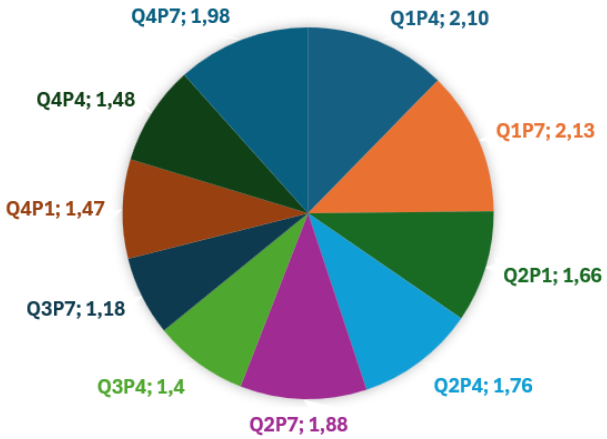


Figure 33: Shannon Wiener diversity index (H') with species diversity for the different cruises and seasons.

The Shannon Wiener equitability index (E) showed that the highest species evenness was found in March for station P4 (E=0.818) and the lowest in August at P4 (E=0.281). For Station P1 the highest evenness was found in December (E=0.706), and for Station P7 it was in March (E=0.805) (Figure 34).

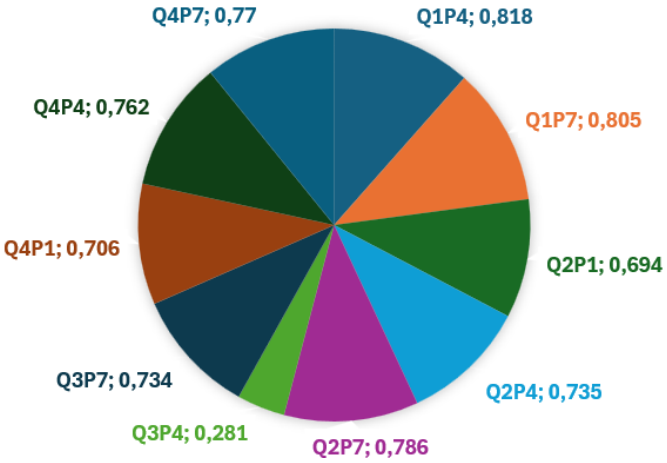


Figure 34: Shannon equitability index with the species evenness for the different cruises and stations.

4. Discussion

The aim of this thesis was to investigate the seasonal differences in plankton communities along a geographic gradient in the Barents Sea. This was done by estimating abundance as well as growth and grazing rates of phytoplankton and microzooplankton. The findings were then compared to scientific studies done in the same area. The results showed that there were seasonal differences in the phytoplankton abundance, with the highest phytoplankton abundance in the spring/summer compared to the winter. With higher microzooplankton abundance in later summer. The grazing rates for microzooplankton was not significantly different for all seasons, which indicates that microzooplankton finds others sources of prey and that Arctic plankton are more dormant in winter.

4.1 Environmental conditions

Studying the environmental conditions are important for understanding how the dynamics in the plankton communities varies seasonally. Phytoplankton growth is affected by the stability of the water column, light and nutrients. The temperatures ranged from -1.86°C at P4 in December to 2.79°C for P7 in August. Along the geographical gradient the temperatures decreased from P1 to P4 and P7 due to ice formation, in December. While the the salinity from P1 to P4 and P7 decreased due to ice melting in summer.

There was observed seasonality in the geograophical gradient with dominance of low temperature and low salinity ArW at P7. Further south, at P4 the water masses had Arctic characteristics with layers of AW, BW and BSW, with signs of ice melting in the summer. P7 also showed signs of ice melting in the summer. The water column at P7 in March and May was mixed with stratification down to around 50-70 m, which seemed to be temperature driven. In August the surface layers were more stratified, that the sea ice had started to melt, was evident with the low salinities and presence of MW. Which indicates that the stratification in August was salinity driven. In December there was a 40 m layer of ArW that was mixed with stratification further down in the water column. P4 in March had a water column that consisted of ArW that was stratified. In May the water column was mixed with ArW down to around 100 m, further down in the water column there was stratification. In August the top 20 m of the water column was stratified with MW. December had surface layers of ArW extending to 90 m depth. At P1 the whole water column was mixed in May and in December it was mixed AW down to 200 m. This is consistent with literature and studies done in the Barents Sea that showed that the southern region is dominated by AW, and the north by ArW, with inflow of BW and BSW (Loeng, 1991).

In AW the spring bloom has been detected in the last half of May (Melle & Skjoldal, 1998). The water column in P1 in May was mixed without stratification (Figure 8), thus indicating it was not in bloom conditions. Which is consistent with spring blooms happening in AW when the water column has stabilised (Melle & Skjoldal, 1998). The sampling done in late April/early May in P1, therefore most likely missed the spring bloom.

Station P7 had the lowest Chl *a* concentrations, which could be due to light limitation. Bare melting ice that is 3 m can have 3% of irradiance penetrating to the surface waters and for 1 m thick ice 15% can penetrate (Light et al., 2008). Thus, for station P7 in March, May and August where the sea ice thickness was around 1 m, the low Chl *a* concentrations and phytoplankton abundance in spring, is likely due to light limitation.

4.2 Phytoplankton and zooplankton interactions

4.2.1 Community composition

From March to May the observed increase in abundance for the phytoplankton community was mostly due to unidentified flagellates (<5 µm) that formed a bloom. During that time a community shift from Cryptophyta dominating to flagellates and diatoms occurred. Flagellates that were 2-10 µm have previously been observed to be an important part of the early-spring bloom in the Arctic (Degerlund & Eilertsen, 2010; Rat'kova & Wassmann, 2002; Sherr et al., 2003). This is consistent with May experiencing pre-bloom conditions and the findings of high abundance of unidentified flagellates <5 µm in May.

The increase in abundance of diatoms from March to May could also indicate the onset of a bloom, without having reached peak conditions yet. This is supported by spring blooms observed after mid-May in the Barents Sea, following the sea ice retreat (Dong et al., 2020). The most abundant diatoms across all seasons were *Thalassiosira* spp. and *Chaetoceros* spp. which is consistent with previous studies, as these centric diatoms are known for being abundant and important in the Barents Sea (Degerlund & Eilertsen, 2010; Wassmann et al., 1999). The decrease in phytoplankton abundance from spring to summer can be explained by post-bloom conditions, where there were less flagellates, but still some diatoms. The cryptophyte *Leucocryptos marina* was abundant in the winter. This is in agreement with observations made in 1988 in March, that showed that *L. marina* was abundant in both ArW and AW in the Barents Sea (Degerlund & Eilertsen, 2010).

Usually *Phaeocystis pouchetii* has been found to be very abundant in the Barents Sea in spring (Degerlund & Eilertsen, 2010; Rat'kova & Wassmann, 2002). In this thesis, no dominance of *Phaeocystis* spp. was found. However, this could be due to taxonomic error, as it can be challenging to identify *Phaeocystis* spp. using microscopy. This is due to *Phaeocystis* spp. colonies being hard to preserve, so they usually occur as small single cells in preserved samples. It could also be explained by *P. pouchetii* being most abundant in AW in the Barents Sea with low stratification (Olli et al., 2002), so it may be speculated that for Q3 at station P1 this species would have been more abundant.

The observed increase in abundance for heterotrophic protists from March to May and the following decrease in abundance from May to August suggests that the heterotrophic protist followed the increased abundance of phytoplankton. This pattern confirms the hypothesis that heterotrophic abundance would follow increases in autotrophic abundance (Head et al., 2000; Søreide et al., 2010). It also further supports the assumption that the peak bloom conditions were between the May and August. Even though there were significant differences in abundance, the community structure stayed the same for every season. For all seasons and stations heterotrophic dinoflagellates under 50 µm were most abundant, in addition to, ciliates larger than 20 µm that were also very abundant. This is similar to findings by other studies (e.g (Menden-Deuer et al., 2018)), that found that heterotrophic dinoflagellates and larger ciliates usually dominate the microzooplankton biomass and are important grazers in polar waters (Franzè & Lavrentyev, 2014; Levinsen et al., 2000). Heterotrophic dinoflagellates have been found to prey on large diatoms, but they have also been found to not be selective in their feeding, and be able to persist in low food conditions (Sherr & Sherr, 2007), which can explain their high abundance over all seasons. The most abundant group of heterotrophic protists was Athecate DF M, with *Gymnodinium* spp. being most abundant. This is inline with studies done in the Barents Sea in late August 2018 and 2019

(Kohlbach et al., 2023), and in Disko Bay, Greenland in April and May 2011 (Menden-Deuer et al., 2018).

4.2.2 Growth

Growth rates for phytoplankton were found to be different for May and December at P1, from March to May, and May to August at P4, and for May and August at P7. There was also a difference in August between growth rates for P4 and P7. For microzooplankton there was a difference in growth rates for May and August, and August and December for P4, and for May and August at P7. There were no differences between stations.

The increase in growth of phytoplankton from March to May for P4 and P7 is consistent with the pre-bloom conditions, due to sufficient nutrient (Jones et al., 2022) and increasing light availability. Which also indicates that the plankton community is bottom-up controlled early in the season (Wassmann, 1998). The following decrease in growth of autotrophs in August can be explained by post-bloom conditions, which is further supported by the increase in growth of heterotrophs from May to August (Sherr et al., 2003) This indicates top-down control by microzooplankton on phytoplankton later in the season.

No significant differences between March and December for all stations can indicate that there are similar conditions for growth during the winter, when light limitation occurs. The fact that some growth of ciliates and dinoflagellates was observed in winter can be due to their wider temperature tolerance for growth (Franzè & Lavrentyev, 2014). The negative growth of ciliates can also be explained by trophic interactions between microzooplankton, with dinoflagellates that are known to prey on ciliates (Hansen, 1991). This could indicate that there is activity in the winter, but the zooplankton is more dormant than in the spring. Which supports the hypothesis that the Arctic plankton community rests in winter, as a survival strategy (Hirche, 1991).

In the growth rates of phytoplankton and microzooplankton for the different treatments with added copepods, there were no significant differences compared to 100% end throughtout the seasons. However, for P7 there was lower growth of Pennate diatoms > 20 µm in May and August, which is consistent with *Calanus* spp. feeding on diatoms (Søreide et al., 2008). For P4 there was no trend towards lower growth of diatoms with addition of *Calanus* spp., there was however, lower growth of heterotrophic protists. Thus indicating that copepods frequently use other prey items, such as ciliates, as demonstrated by Calbet & Saiz (2005). Ciliates are also more exposed to predation by copepods in post-bloom waters (Levinsen et al., 2000). This could be an indication for top-down control. At P1 there was no trend towards feeding preference for any of the plankton groups.

There was no difference in the growth rate for phytoplankton in *Oithona* spp., compared to the 100% end for all seasons and stations. However, microzooplanton growth rates were higher in 100% end for station P4 in august and P7 in December, compared to *Oithona* spp. There was a trend for lower growth of ciliates for P7 and P4, which is supported by a previous study that found selective feeding of *Oithona* spp. on ciliates. (Castellani et al., 2008)

No nutrient stimulated growth was observed for any of the treatments for the different stations and seasons. This indicates that there were sufficient nutrients for growth in spring.

4.2.3 Grazing

Grazing rates were not found to be significantly different for the different seasons and between stations. This could be explained by the microzooplankton finding sufficient amounts of prey in winter, which could be related to within-zooplankton predation (Franzé & Modigh, 2013). It is hypothesized that mesozooplankton such as copepods shift their diet to microzooplankton prey in the winter, due to lower abundance of autotrophs (Søreide et al., 2008). This could explain why there were no significant differences in the grazing rates for *Calanus* spp., and *Oithona* spp., compared to the 100% end. *Calanus* spp. is known to graze on ciliates more efficiently than on phytoplankton (Aberle et al., 2015; Broglio et al., 2004; Levinsen et al., 2000). Usually, *Calanus glacialis* feed on ice-algae when available, then phytoplankton during the spring bloom. When there are low abundance of phytoplankton, such as winter, *C. glacialis* turns to omnivory (Cleary et al., 2017; Søreide et al., 2008). This could indicate that top-down control is important in plankton community and ecosystem (Verity et al., 2002).

The growth rates of microzooplankton were only higher than the growth rates of phytoplankton in December at P7 and August for P4, could indicate that the fraction of primary production removed by grazing was variable (Menden-Deuer et al., 2018). That microzooplankton growth rates were only higher than phytoplankton growth rates for two seasons and two stations, could also be a possible explanation for there not being any significant differences in grazing between seasons.

That there were no significant differences in grazing rates in 100% compared to *Calanus* spp, and *Oithona* spp., could indicate that microzooplankton grazing has equal or higher grazing potential than copepods (Löder et al., 2011).

4.2.4 Growth & Grazing Chl *a*

December at P1 was the only station to not have any growth of Chl *a*, which could be a combination of light limitation and a mixed water column with very low Chl a (Figure 8B). Low growth rates have been documented in stratified waters in the mediterranean (Modigh & Franzè, 2009).

That there were negative growth rates only for P7 in August could be explained by post-bloom conditions, as negative growth of Chl *a* has been found in the Arctic Ocean in the summer previously (Calbet et al., 2011). Using Chl *a* as a proxy for phytoplankton is not as presice as using cell counts, since it doesn't capture the complexity of interactions within the plankton community.This is mainly related to the fact that, the chlorophyll concentration per cell can vary depending on e.g. light and nutrient conditions (Calbet et al., 2011).

4.2.5 Growth & Grazing Total Abundance

The positive growth observed from March to August is consistent with findings of post-bloom conditions in August, with the abundances having increased during spring. The fact that growth rates of the heterotrophic protists did not show the same trend, could be related to the complexity of feeding interactions within zooplankton communities (Franzè & Lavrentyev, 2014). The increase in grazing rate from May to August is

consistent with increases in microzooplankton abundance as a response to the increases in phytoplankton abundance (Sherr et al., 2003).

4.2.6 Weakness of the methods

The results from the experiment could have been affected by mechanical (shear) stress happening when sampling and filtering the seawater. It should also be noted that there could have been biases in setting up and executing the dilution experiment. Even though there was a protocol, the experiment was executed by different people on the Nansen Legacy cruises. The light regime in the lab could also have led to higher growth rates for phytoplankton, due to the climate controlled room not being adjusted for the presice light regime in the field. The samples could also have been affected by the non-continous rotation of the bottles, as they were turned manually, which could have led phytoplankton to settle on the bottom of the incubation bottles.

Also overestimation of microzooplankton can happen when using the dilution technique. This could be due to exclusion of mesozooplankton predators, and starvation of microzooplankton in the diluted sample. In addition the mortality rates of ciliates and large dinoflagellates may not be estimated well (Calbet et al., 2011). It should also be noted that grouping microzooplankton into size classes and groups could have masked dynamic processes in the community (Franzè & Lavrentyev, 2014). Using species diversity and functional traits of specific taxa and species would probably have provided more detailed information about the plankton dynamics.

4.3 Shannon-Wiener diversity indices

That the highest diversity was found in late winter is not uncommon for Arctic plankton communities as nutrient concentrations are high, and relatively constant during that time of the year. It could also be due to light limitation, that prevents phytoplankton from blooming, and the subsequent increase in microzooplankton abundance.

Maybe the community was getting prepared already for the spring bloom, as May had lower diversity but higher abundance. Overall, the least diverse season was late summer. This could be related to pre-bloom conditions, with less species richness, as June/July is the season when species diversity is known to peak (Rat'kova & Wassmann, 2002). Evenness showed similar patterns except for P4 in August that showed lower evenness, which could indicate that there was less diversity and a dominance of certain groups during this time of the year.

4.4 Future of the Arctic

Even though the changes in ice-cover can potentially be explained by seasonal cycle or interannual changes, the rate at which the changes are currently happening are faster than expected . Studies show that warming can lead to higher growth rates of microzooplankton (Aberle et al., 2015), which can lead to increased top-down control of microzooplankton on phytoplankton. Warmer temperature can also lead to changes in the timing of phytoplankton blooms (Aberle et al., 2015). Which can lead to a mismatch in zooplankton feeding as they have adapted their spawning to timing of phytoplankton blooms (Søreide et al., 2010).

It is unknown exactly how plankton will respond to climate change in the future, however, the main effects will most likely be in shifts in seasonal dynamics, species composition, and population size structure (Winder & Sommer, 2012).

5 Concluding remarks

The aim of this study was to look at seasonal differences in growth and grazing rates of phytoplankton and microzooplankton along a geographical gradient in the Barents Sea. It was found that the highest phytoplankton abundances were in May due to pre spring-bloom conditions. The microzooplankton abundances increased in August, due to plenty of prey having been available after the spring bloom. The highest plankton diversity was found in March at P7, due to sufficient nutrients and increasing light conditions, indicating that the community was in pre-bloom conditions. The lowest diversity for all cruises was found at P1, thus the hypothesis of station P1 being more mixed, and therefore arriving at bloom conditions later than P4 and P7 was kept.

Addition of *Calanus* spp., and *Oithona* spp. only led to significant difference in growth rates in P4 in August, which indicates that mesozooplankton can turn to omnivory when there are low abundances of phytoplankton. Microzooplankton growth rates were not significantly different in December and March, inidicating that Arctic zooplankton are more dormant in the winter as a survival strategy. However, there was positive growth of microzooplankton, which could indicate internal predation, due to low abundances of phytoplankton.

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Appendix A

Table A.1: Watermass characteristics used to characterise the different watermasses found. Characteristics defined by Loeng (1991) and Harris et al. (1998).

Watermass	**Temperature (°C)**	**Salinity**
Atlantic Water (AW)	1.0-3.0	<34.7
Arctic Water (ArW)	<0.0	34.3-34.8
Coastal Water (CW)	>2.0	<34.7
Polar Front Water (PFW)	-0.5-2.0	34.8-35
Bottom Water (BW)	<-1.5	>35.0
Melt Water (MW)	>0.0	<34.2
Barents Sea Water (BSW)	-1.5-2.0	34.7-35.0

Appendix B

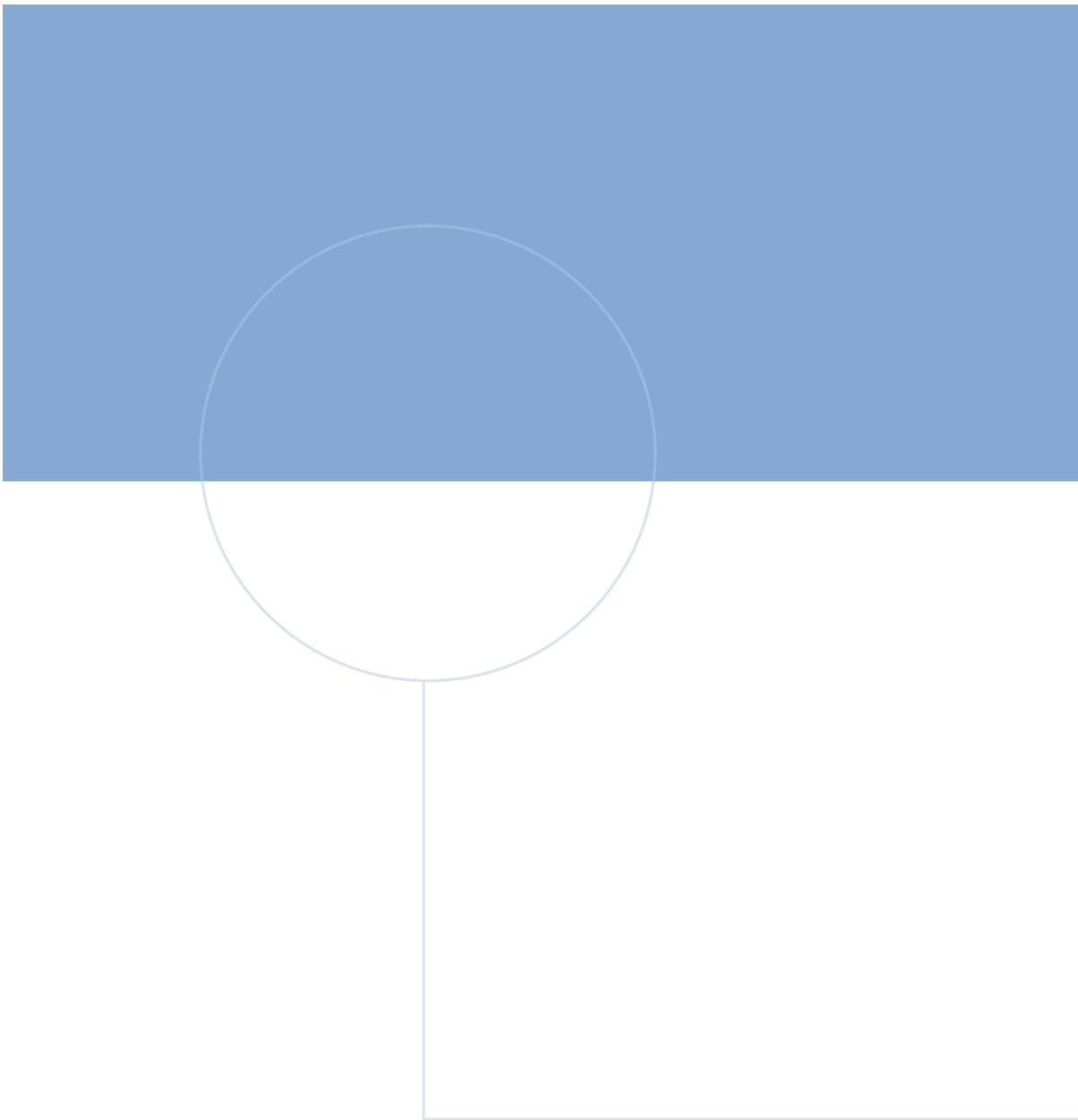
Table B. 1: All species collected with Phylum, trophic mode, size and what sorting category they were put into. Species were sorted using Krabet et al., 2010, * indicates nordicmicroalgae.org was used and (#) indicates that Encyclopedia of Life (eol.org) was used to find trophic mode.

Phylum	Species	Trophic mode	Size (µm)	Sorting category
Bacillarophyta	*Amphipora* spp.	Autotrophic	20-50	Pennate > 20 µm
Bacillarophyta	*Attheya septentrionalis*	Autotrophic	10-20	Centric < 20 µm
Bacillarophyta	*Bacillaria* spp.	Autotrophic	50-100	Pennate > 20 µm *
Bacillarophyta	Bacillariales indet. (ellipic cylinder)	Autotrophic	20-50	Pennate > 20 µm
Bacillarophyta	Bacillariales indet. (rhombic prism)	Autotrophic	50-100	Pennate > 20 µm
Bacillarophyta	*Bacteriastrum hyalinum*	Autotrophic	20-50	Centric > 20 µm
Bacillarophyta	*Bacteriosira bathyomphala*	Autotrophic	10-20	Centric < 20 µm
Bacillarophyta	Biddulphiales indet.	Autotrophic	10-20	Centric < 20 µm
Bacillarophyta	*Ceratulina* spp.	Autotrophic	50-100	Centric > 20 µm
Bacillarophyta	*Chaetoceros concavicornis*	Autotrophic	20-50	*Chaetoceros* spp.
Bacillarophyta	*Chaetoceros socialis/gelidus*	Autotrophic	5-10	*Chaetoceros* spp.
Bacillarophyta	*Chaetoceros calcitrans*	Autotrophic	NA	*Chaetoceros* spp.
Bacillarophyta	*Chaetoceros laciniosus*	Autotrophic	10-20	*Chaetoceros* spp.
Bacillarophyta	*Chaetocers furcillatus*	Autotrophic	5-10	*Chaetoceros* spp.
Bacillarophyta	*Chaetoceros decipiens*	Autotrophic	20-50	*Chaetoceros* spp.
Bacillarophyta	*Chaetoceros wighamii*	Autotrophic	NA	*Chaetoceros* spp.
Bacillarophyta	*Chaetoceros diadema*	Autotrophic	NA	*Chaetoceros* spp.
Bacillarophyta	*Chaetoceros tenuissimus*	Autotrophic	<5	*Chaetoceros* spp.
Bacillarophyta	*Chaetoceros* spp.	Autotrophic	20-50	*Chaetoceros* spp.
Bacillarophyta	*Cocconeis* spp.	Autotrophic	20-50	Pennate > 20 µm
Bacillarophyta	*Cosinodiscus* spp.	Autotrophic	50-100	Centric > 20 µm
Bacillarophyta	*Cyclotella* spp.	Autotrophic	10-20	Centric < 20 µm
Bacillarophyta	*Cylindrotheca closterium*	Autotrophic	10-20	Needleshaped diatoms
Bacillarophyta	*Dactyliosolen* spp.	Autotrophic	50-100	Centric > 20 µm *
Bacillarophyta	*Entomoneis* spp.	Autotrophic	50-100	Pennate > 20 µm
Bacillarophyta	*Eucampia groenlandica*	Autotrophic	20-50	Centric > 20 µm
Bacillarophyta	*Eucampia zoidiacus*	Autotrophic	20-50	Centric > 20 µm *
Bacillarophyta	*Fossulaphycus arcticus*	Autotrophic	20-50	Pennate > 20 µm *
Bacillarophyta	*Fragilaria* spp.	Autotrophic	100-200	Pennate > 20 µm
Bacillarophyta	*Fragilariopsis cylindricus/oceanica*	Autotrophic	10-20	Pennate < 20 µm
Bacillarophyta	*Fragilariopsis nana*	Autotrophic	10-20	Pennate < 20 µm
Bacillarophyta	*Fragilariopsis* spp.	Autotrophic	10-20	Pennate < 20 µm
Bacillarophyta	*Grammatophora marina*	Autotrophic	10-20	Pennate < 20 µm
Bacillarophyta	*Guinardia delicatula*	Autotrophic	20-50	Centric > 20 µm *
Bacillarophyta	*Gyrosigma/Pleurosigma* spp.	Autotrophic	100-200	Pennate > 20 µm
Bacillarophyta	*Lennoxia faveolata*	Autotrophic	10-20	Centric < 20 µm
Bacillarophyta	*Leptocylindrus danicus*	Autotrophic	20-50	Centric > 20 µm
Bacillarophyta	*Leptocylindrus minimus*	Autotrophic	10-20	Centric < 20 µm
Bacillarophyta	*Licmophora* spp.	Autotrophic	20-50	Pennate > 20 µm *
Bacillarophyta	*Melosira arctica*	Autotrophic	10-20	Centric < 20 µm *
Bacillarophyta	*Navicula pelagica*	Autotrophic	20-50	Pennate > 20 µm
Bacillarophyta	*Navicula septentrionalis*	Autotrophic	20-50	Pennate > 20 µm

Bacillarophyta	*Navicula* spp.	Autotrophic	20-50	Pennate > 20 µm
Bacillarophyta	*Navicula vanhoeffenii*	Autotrophic	20-50	Pennate > 20 µm
Bacillarophyta	*Nitzschia* spp.	Autotrophic	20-50	Pennate > 20 µm
Bacillarophyta	*Nitzschia longissima*	Autotrophic	20-50	Pennate > 20 µm
Bacillarophyta	*Nitzschia promare*	Autotrophic	20-50	Pennate > 20 µm
Bacillarophyta	*Nitzschia frigida*	Autotrophic	50-100	Pennate > 20 µm
Bacillarophyta	*Nitzschia reversa*	Autotrophic	100-200	Pennate > 20 µm
Bacillarophyta	*Odontella aurita*	Autotrophic	20-50	Centric > 20 µm *
Bacillarophyta	*Pauliella taeniata*	Autotrophic	20-50	Centric > 20 µm
Bacillarophyta	*Pseudo-nitzschia delicatissima*	Autotrophic	50-100	Pennate > 20 µm
Bacillarophyta	*Pseudo-nitzschia seriata*	Autotrophic	50-100	Pennate > 20 µm
Bacillarophyta	*Pseudosolenia calcar-avis*	Autotrophic	50-100	Pennate > 20 µm *
Bacillarophyta	*Rhizosolenia* spp.	Autotrophic	50-100	Needleshaped diatoms *
Bacillarophyta	*Shinodiscus bioculatus*	Autotrophic	20-50	Centric > 20 µm
Bacillarophyta	*Skeletonema costatum*	Autotrophic	5-10	Centric < 20 µm
Bacillarophyta	*Synedropsis hyperborea*	Autotrophic	NA	Needleshaped diatoms
Bacillarophyta	*Thalassionema nitzshiodes*	Autotrophic	20-50	Pennate > 20 µm *
Bacillarophyta	*Thalassiosira antarctica* var. *borealis*	Autotrophic	20-50	*Thalassiosira* spp.
Bacillarophyta	*Thalassiosira hyalina*	Autotrophic	20-50	*Thalassiosira* spp.
Bacillarophyta	*Thalassiosira nordenskioeldii*	Autotrophic	10-20	*Thalassiosira* spp.
Bacillarophyta	*Thalassiosira* spp.	Autotrophic	20-50	*Thalassiosira* spp.
Bacillarophyta	*Thalassiosira* spp.	Autotrophic	50-100	*Thalassiosira* spp.
Bacillarophyta	*Thalassiosira minima*	Autotrophic	10-20	*Thalassiosira* spp.
Myzozoa	*Actiniscus pentasterias*	Heterotrophic	20-50	Athecate DF M *
Myzozoa	*Alexandrium* spp.	Autotrophic	20-50	Autotrophic DF
Myzozoa	*Amphidinium crassum*	Heterotrophic	20-50	Athecate DF M (#)
Myzozoa	*Amphidinium longum*	Heterotrophic	20-50	Athecate DF M (#)
Myzozoa	*Amphidinium* spp.	Heterotrophic	20-50	Athecate DF M
Myzozoa	*Amphidinium sphenoides*	Autotrophic	20-50	Autotrophic DF
Myzozoa	*Amphidoma* spp.	Mixotrophic	10-20	Thecate DF S (#)
Myzozoa	*Azadinium* spp.	Autotrophic	10-20	Autotrophic DF (#)
Myzozoa	*Dicroerisma psilonereiella*	NA	20-50	Thecate DF M
Myzozoa	Dinophyceae indet. (prolate spheroid)	Mixotrophic	20-50	Athecate DF M *
Myzozoa	Dinophyceae indet. (thecate)	Mixotrophic	20-50	Thecate DF M
Myzozoa	*Dinophysis norvegica*	Mixotrophic	50-100	Thecate DF L *
Myzozoa	*Dinophysis* spp.	Mixotrophic	20-50	Thecate DF M *
Myzozoa	Diplopsalis indet.	Heterotrophic	20-50	Thecate DF M
Myzozoa	*Gonyaulax* spp.	Autotrophic	20-50	Autotrophic DF *
Myzozoa	*Gymnodinium* spp.	Mixotrophic	50-100	Athecate DF L
Myzozoa	*Gymnodinium* spp.	Mixotrophic	10-20	Athecate DF S
Myzozoa	*Gymnodinium* spp.	Mixotrophic	20-50	Athecate DF M
Myzozoa	*Gyrodinium flagellare*	Autotrophic	10-20	Autotrophic DF
Myzozoa	*Gyrodinium* spp.	Heterotrophic	50-100	Athecate DF L
Myzozoa	*Gyrodinium* spp.	Heterotrophic	10-20	Athecate DF S
Myzozoa	*Gyrodinium* spp.	Heterotrophic	20-50	Athecate DF M
Myzozoa	*Gyrodinium spirale*	Heterotrophic	50-100	Athecate DF L *
Myzozoa	*Heterocapsa arctica*	Autotrophic	10-20	Autotrophic DF *
Myzozoa	*Katodinium glaucum*	Heterotrophic	20-50	Athecate DF M
Myzozoa	Micracanthodinium claytonii	Heterotrophic	10-20	Athecate DF S
Myzozoa	*Oxyrrhis marina*	Heterotrophic	10-20	Athecate DF S *

Myzozoa	*Oxytoxum gracile*	Mixotrophic	20-50	Thecate DF M *
Myzozoa	*Oxytoxum* spp.	Mixotrophic	20-50	Thecate DF M ‘
Myzozoa	*Phalacroma rotundatum*	Mixotrophic	20-50	Thecate DF M *
Myzozoa	*Pronoctiluca pelagica*	Heterotrophic	20-50	Athecate DF M (#)
Myzozoa	*Pronoctiluca spinifera*	Heterotrophic	20-50	Athecate DF M (#)
Myzozoa	*Prorocentrum gracile*	Mixotrophic	20-50	Thecate DF M
Myzozoa	*Prorocentrum micans*	Mixotrophic	50-100	Thecate DF L
Myzozoa	*Prorocentrum minimum*	Mixotrophic	10-20	Thecate DF S *
Myzozoa	*Prorocentrum tirestinum*	Autotrophic	10-20	Autotrophic DF
Myzozoa	*Protoperidinium bipes*	Heterotrophic	20-50	Thecate DF M
Myzozoa	*Protoperidinium brevipes*	Heterotrophic	20-50	Thecate DF M *
Myzozoa	*Protoperidinium curtipes*	Heterotrophic	50-100	Thecate DF L
Myzozoa	*Protoperidinium minitum*	Heterotrophic	20-50	Thecate DF M
Myzozoa	*Protoperidinium pellucidum*	Heterotorphic	20-50	Thecate DF M
Myzozoa	*Protoperidinium pyriforme*	Heterotrophic	20-50	Thecate DF *
Myzozoa	*Scippsiella* spp.	Mixotrophic	20-50	Thecate DF M
Myzozoa	*Torodinium robustum*	Heterotrophic	20-50	Athecate DF M
Myzozoa	*Tripos arcticus*	Mixotrophic	50-100	Thecate DF L (#)
Myzozoa	*Tripos arcticus*	Mixotrophic	50-100	Thecate DF L *
Myzozoa	*Tripos muelleri*	Mixotrophic	50-100	Thecate DF L *
Euglenozoa	*Eutreptiella* spp.	Autotrophic	20-50	Others
Euglenozoa	*Euglena* spp.	Autotrophic	50-100	Others *
Telonemia	*Telonema antarcticum*	Heterotrophic	10-20	Others (#)
Radiozoa	Nasselaria indet.	Heterotrophic	20-50	Others
Radiozoa	Radiozoa indet.	Heterotrophic	20-50	Others
Cyanobacteria	*Romeria* spp.	Autotrophic	50-100	Others *
Cyanobacteria	Cyanophyceae indet.	Autotrophic	5-10	Others
Cyanobacteria	*Woronichinia* spp.	Autotrophic	5-10	Others
Cercozoa	*Ebria tripartite*	Heterotrophic	25	Others
Heliozoa	*Heterophrys spp.*	Heterotrophic	NA	Others
Amoebozoa	Amoeba indet.	Heterotrophic	5-20	Others
Flagellates	“Flagellates”, unidentified	Mixotrophic	<5	Flagellates
Ciliophora	*Acanthostomella norvegica*	Heterotrophic	20-50	Loricate M
Ciliophora	*Laboea strobilia*	Heterotrophic	50-100	Loricate L *
Ciliophora	*Lohmaniella oviformis*	Heterotrophic	10-20	Loricate S
Ciliophora	*Myrionecta rubra*	Heterotrophic	20-50	Aloricate M
Ciliophora	*Strombidium* spp.	Heterotrophic	50-100	Aloricate M
Ciliophora	*Strombidium conicum*	Heterotrophic	50-100	Aloricate L
Ciliophora	*Strombidium emergens*	Heterotrophic	20-50	Aloricate M
Ciliophora	*Strombidium acutum*	Heterotrophic	20-50	Aloricate M
Ciliophora	*Strombidium epidemum*	Heterotrophic	10-20	Aloricate S
Ciliophora	*Strombidium capitatum*	Heterotrophic	20-50	Aloricate M
Ciliophora	*Strombidium wulffi*	Heterotrophic	50-100	Aloricate L
Ciliophora	*Leegardiella sol*	Heterotrophic	20-50	Loricate M
Ciliophora	*Mesodinium pulex*	Heterotrophic	10-20	Loricate S
Ciliophora	“philasterine scuticociliates”	Heterotrophic	5-15	Aloricate S
Ciliophora	“pleuronematine scuticociliates”	Heterotrophic	20-50	Aloricate M
Ciliophora	*Salpingella acuminata*	Heterotrophic	20-50	Loricate M
Ciliophora	*Tontonia turbinate*	Heterotorphic	50-100	Loricate L
Ciliophora	*Parafavella denticulate*	Heterotrophic	50-100	Loricate L *

Ciliophora	*Tontonia gracillima*	Heterotorphic	20-50	Loricate M
Choanozoa	*Monosiga marina*	Heterotrophic	5-10	Others
Choanozoa	*Bicosta minor*	Heterotrophic	10-20	Others
Choanozoa	Choanoflaggelatea indet.	Heterotorphic	5-10	Others
Ochcrophyta	*Dictyocha speculum*	Autotrophic	20-50	Silicoflagellates
Ochrophyta	*Dictyocha octonaria*	Autotrophic	10-20	Silicoflagellates
Ochrophyta	*Dinobryon* spp.	Mixotrophic	10-20	*Dinobryon* spp.
Ochrophyta	*Apedinella radians*	Autotrophic	5-10	Silicoflagellates *
Ochrophyta	*Chattonellale spp.*	Autotrophic	20-50	Silicoflagellates
Ochrophyta	Silicoflagellates	Mixotrophic	NA	Silicoflagellates (#)
Haptophyta	*Phaeocystis globosa*	Autotrophic	5-10	Haptophyta
Haptophyta	Prymnesiales indet.	Autotrophic	10-20	Haptophyta
Haptophyta	*Chrysochromulina birgeri*	Autotrophic	10-20	Haptophyta
Haptophyta	Coccolithales indet.	Autotrophic	NA	Haptophyta
Haptophyta	Coccolithophyceae indet.	Autotrophic	NA	Haptophyta
Haptophyta	*Corymbellus aureus*	Autotrophic	NA	Haptophyta
Cryptophyta	Cryptophyceae indet.	Autotrophic	10-20	Cryptophyta
Cryptophyta	*Hemiselmis* spp.	Autotrophic	5-10	Cryptophyta
Cryptophyta	*Teleaulax* spp.	Autotrophic	NA	Cryptophyta
Cryptophyta	*Leucocryptos marina*	Autotrophic	10-20	Cryptophyta
Cryptophyta	*Katablepharis remigera*	Autotrophic	NA	Cryptophyta
Cryptophyta	*Plagioselmis* spp.	Autotrophic	NA	Cryptophyta (#)
Chlorophyta	*Mantoniella squamata*	Autotrophic	NA	Chlorophyta
Chlorophyta	*Pseudoscuorfieldia marina*	Autotrophic	5-10	Chlorophyta
Chlorophyta	*Pyramimonas* spp.	Autotrophic	10-20	Chlorophyta
Chlorophyta	*Pterosperma cristatum*	Autotrophic	5-10	Chlorophyta (#)
Chlorophyta	*Pterosperma vanhoeffenii*	Autotrophic	10-30	Chlorophyta (#)
Chlorophyta	*Coelastrum* spp.	Autotrophic	NA	Chlorophyta (#)
Chlorophyta	*Pachysphaera* spp.	Autotrophic	NA	Chlorophyta (#)
Chlorophyta	*Monoraphidium* spp.	Autotrophic	NA	Chlorophyta (#)



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