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Epibenthic community structure in Northeast Greenland and the Kitikmeot Sea in the Canadian Arctic Archipelago

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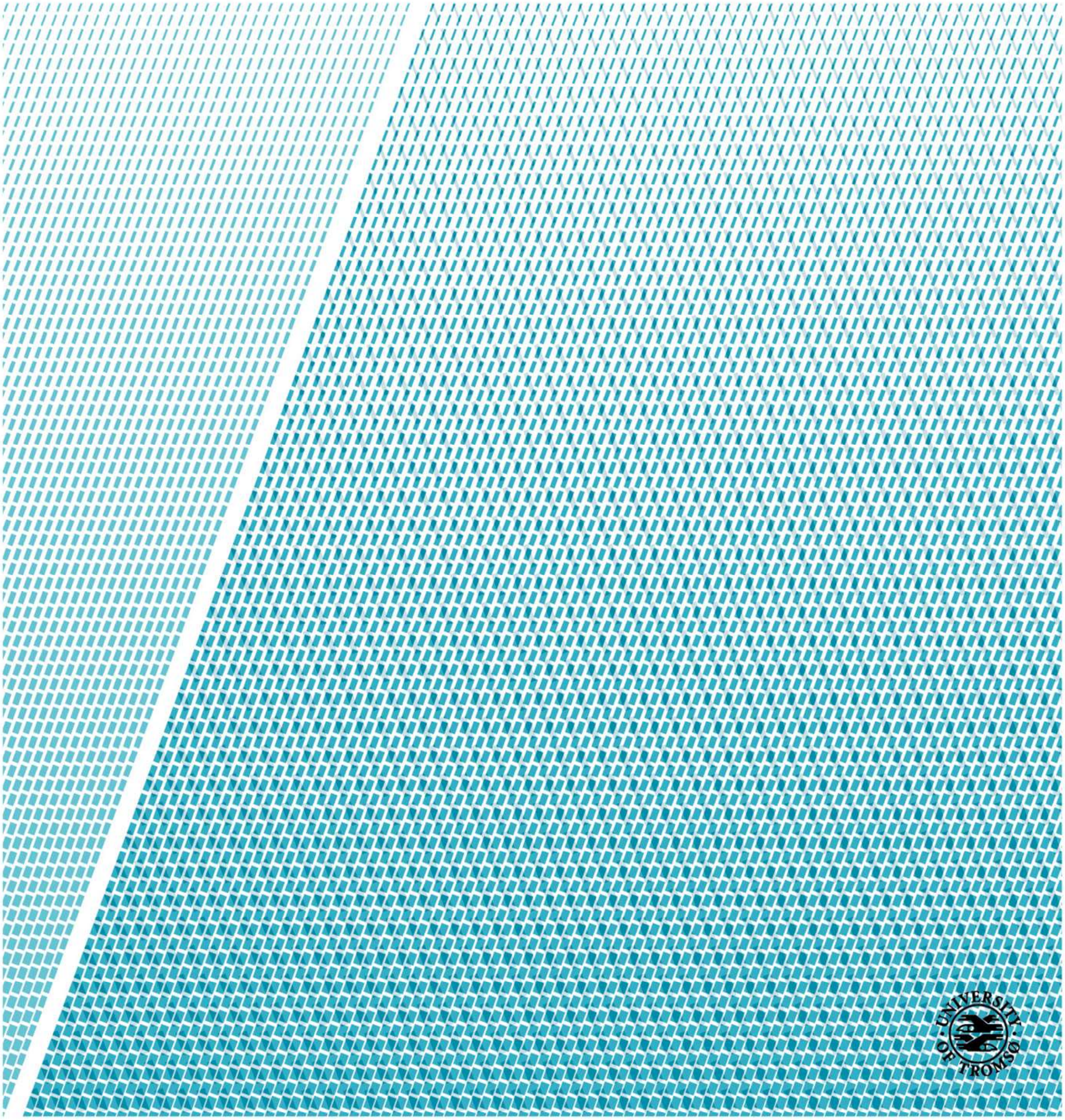
Rosalyn Fredriksen
BIO-3950 – Master’s thesis in Biology, May 2018



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Abbreviations

ANOSIM – Analysis of Similarities

BIO-ENV – Biological-Environmental analysis

CAA – Canadian Arctic Archipelago

Campelen trawl – Campelen 1800 Shrimp trawl

Chl *a* – Chlorophyll *a*

CTD – Conductivity-Temperature-Depth profiler

EGC – East Greenland Current

g ww – gram wet weight

HCA – Hierarchical Cluster Analysis

IMR – Institute of Marine Research

NEG – Northeast Greenland

nMDS – non-metric Multidimensional Scaling

No. of ind. – number of individuals

NEW Polynya – Northeast Water Polynya

PCA – Principal Component Analysis

SIMPER – Similarity Percentages

SIMPROF – Similarity of Profile Analysis

UiT – The Arctic University of Norway, Tromsø

WSC – West Spitzbergen Current

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1 Abstract

Climate warming in the Arctic results in increased human use of Arctic shelf regions through oil and gas development and increased shipping. Such pressures necessitate the closing of knowledge gaps in poorly studied areas, here two areas located at outflow shelves in the Arctic, to record the current status of epibenthic marine ecosystems. This study characterizes epibenthic community structure, feeding strategies composition and their relation to environmental parameters in Northeast Greenland (NEG) and the Kitikmeot Sea in Nunavut in the Canadian Arctic Archipelago (CAA). Sample collection of trawled epibenthos in NEG was conducted at 33 stations at depths between 65 – 1011 m in August 2015 and September 2017, whereas images of epibenthos in the Kitikmeot Sea were taken at seven stations at depths between 20 – 93 m in August 2016. Abundance estimates were provided from both regions, in addition to biomass estimates from NEG. This study improves the inventory list in these regions with 276 putative species in Northeast Greenland collected by Campelen 1800 shrimp and Agassiz trawls and 33 putative species in the Kitikmeot Sea identified by photographic analysis. All taxa identified were known to occur in other Arctic areas. Arthropoda and Echinodermata were the most taxa rich groups in Northeast Greenland and the Kitikmeot Sea, respectively, while Mollusca and Echinodermata the most abundant taxa and Echinodermata was most biomass rich in NEG. In NEG, four geographically contiguous community clusters were recognized, namely fjord, shelf, shelf break and slope communities. Epibenthic community structure and its variability across the stations in NEG was partly explained by environmental drivers that exhibited gradients from the inner part of Bessel Fjord towards the shelf break and slope, with depth and bottom oxygen concentration as the most important factors, in addition to bottom temperature, salinity and turbidity. In the Kitikmeot Sea, feeding strategies strongly reflected the current situation, with suspension feeders present in high current regimes (dominated by hard substrate) and surface deposit feeders present where particles sink to the seafloor (dominated by soft substrate). As more research is ongoing in the Arctic, the inventory list of taxa/species are still expected to expand. Habitat and associated epibenthic community heterogeneity documented on sub-regional to smaller scales across both study areas suggests that site specific environmental assessments must be conducted before human development in Arctic shelf areas.

Key words: Arctic Epibenthos, Epibenthic community structure, Northeast Greenland, Kitikmeot Sea, Canadian Arctic Archipelago, baseline study, image analysis, environmental drivers

2 Introduction

2.1 The human footprint into the Arctic is more visible now than ever

The Arctic Ocean is unique in several ways. It is surrounded by landmasses, which characterizes it as a mediterranean ocean (meaning *Ocean in-between land*) (Jakobsson *et al*., 2012). This mediterranean ocean is often inaccessible since it is seasonally and partly permanently covered by sea ice. Beneath the sea ice lie many secrets hidden from the human knowledge. Even though this region is challenging to access, human curiosity to explore the unknown has not stopped humans from examining the Arctic; an example is the first crossing of Greenland from east to west by the Norwegian scientist and explorer Fridtjof Nansen & Co in 1888 (Nansen 1890). A few decades later, another remarkable expedition could be written down in Norwegian history books when Roald Amundsen completed the first transit through the Northwest Passage in Canadian Arctic Archipelago in 1903 (Amundsen 1908). These regions are mentioned not only because they are both located in the Arctic, but also since their exploration reflects how much humans seeks to explore uncharted and pristine areas. While these two areas have totally different geographical positions and are influenced by distinct water masses, they have several aspects in common: Both regions are parts of shelves where cold water is flowing from the Arctic to the Atlantic (i.e. *Outflow shelves*, see Carmack and Wassman 2006 for details) (Figure 1), they are poorly studied, and yet human development plans are already ongoing in both areas of the Arctic. To contribute to expanding our knowledge of the unknown in the Arctic, this master's thesis will focus on the two regions where the Norwegian explorers sat their first historic footprint in the Arctic, and where much of these regions is yet unknown until today. The purpose of this thesis is to gather more knowledge in these poorly studied regions and to create a better pan-Arctic understanding so we are prepared for future changes before the human footprint will affect these pristine areas.

The Arctic Ocean in general acts as an indicator for anthropogenic pressure and has a significant importance on the global scale in that it functions as a sink for pollutants and CO_2 emissions coming from all over the world (Barrie *et al*., 1992). These compounds are mainly transported by wind and ocean currents and accumulate in the Arctic (Barrie *et al*., 1992). Scientists have shown that this pollution affects Arctic ecosystems (Kelly *et al*., 2007) and there are major concerns that it will affect human health even more (AMAP, 1998). The increase of carbon emissions to the atmosphere are the result of great human activities in industries and transport and have led to a tremendous ice retreat in the Arctic (Comiso *et al*., 2008). Satellite-based estimates have shown that the sea ice has decreased by about 10% per decade since the end of 1970s (Comiso 2002; Comiso *et al*., 2008). Paradoxically, observations show that the sea ice is decreasing even faster than predictive models had forecasted and scientists have assumed that the Arctic will probably be ice free in the summer at the end of the 21st century (Arzel *et al*., 2006). Consequently, there is an urgent need to fill the knowledge gaps in biological community distribution in the Arctic to be able to assess the biological responses to the human impacts.

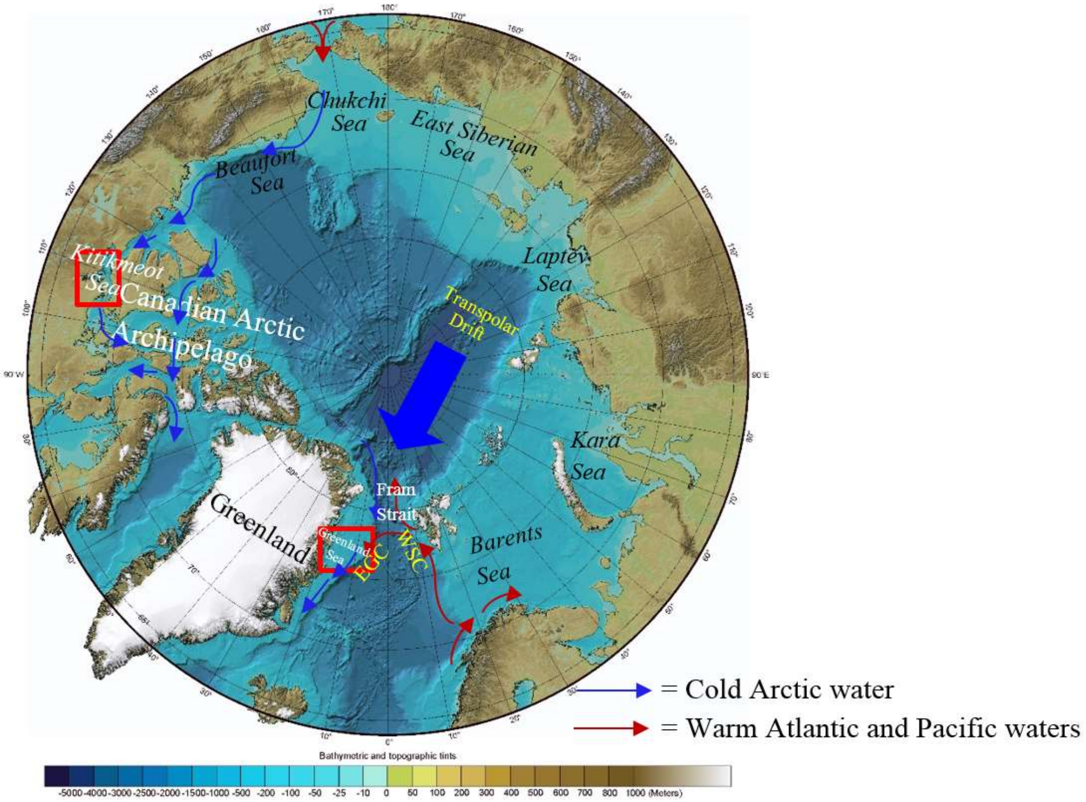


Figure 1: A simplified schematic representation of the ocean currents in the Arctic that influences the two study regions in the Arctic that are located on outflow shelves. The red boxes on map show where the two investigations take place, one on the Northeast Greenland (NEG) shelf in Greenland Sea and the other in the Kitikmeot Sea in Canadian Arctic Archipelago (CAA). The currents that are of importance in the study are EGC = East Greenland Current and WSC = West Spitzbergen Current. The ocean currents are modified from data that were presented in Carmack and Wassmann 2006; Bluhm *et al.,* (2015).

Facing the fact that the Arctic is in drastic change has gathered politicians and scientists from different nations in the Arctic to discuss how to cope with the coming up challenges (Arctic Frontiers conference, Tromsø 2018, "Connecting the Arctic"). The changing Arctic has also become a real revelation for politicians and companies that want to take advantage of the irreversibly retreating sea ice and suggest economic opportunities rather than solutions to mitigate the underlying causes. The Greenlandic newsletter Uulex (abbreviation associated with "*uulia*" which is the Greenlandic term for oil, and "*ex*" is for exploration) published by Ministry of Mineral Resources, Government of Greenland gives yearly updates on where licenses allow search for oil and gas in Greenlandic waters https://www.govmin.gl/en/publications/uulex). The newsletter reveals that there are great activities and huge plans ongoing for the Northeast Greenland (NEG) Shelf that has potential for oil and gas (Uulex 2016). There is concurrently a debate on the other side of Arctic if the Canadian Arctic Archipelago (CAA) should be a shipping route that connects the Atlantic and Pacific oceans in the future (Smith and Stephenson 2013), which can impact the Arctic marine communities. Only in the recent decades, it is possible to see that the number of private yachts and tourist vessels crossing the Northwest Passage has also increased tremendously (Headland *et al*., 2018). Because of little research on the potential impact of marine traffic, little is known on how it has affected the marine communities so far.

Predicting Pan-Arctic changes in the ecosystem remains a challenge for many reasons. Those include a lack of knowledge in inaccessible areas, and constantly changing anthropogenic pressures in space, time and intensity, as well as a lack of mechanistic understanding of change and consequences. Since the sea ice is retreating, research work has been easier, of higher priority and more common in Arctic areas where it was not even conceivable in earlier years. Scientists seek to understand the consequences of human activities in marine environments and how these will affect people (Christiansen *et al*., 2014). Baseline studies are essential to be able to assess the biological responses to the human impacts in the Arctic.

2.2 Epibenthos, their role and patterns in the Arctic and environmental parameters and physical stressors that structure epibenthic communities

Epibenthic invertebrate communities are one of the biological components that are poorly studied in Northeast Greenland and in the Kitikmeot Sea located in CAA and are one of the Arctic ecosystem components in focus that can be influenced by human activities. The term *benthos* originates from the Greek noun and refers in today's marine biology to all living organisms that are associated to the seafloor, of which epibenthos are the organisms that lives on top of the seafloor (*epí* meaning "on top of" from ancient Greek). Epibenthos, but also all benthic invertebrates are an important component in the Arctic food web as they provide a food source for higher trophic levels (Bluhm and Gradinger 2008) and also contribute to recycling of organic materials (Piepenburg *et al*., 1997a; Ambrose *et al*., 2001). Given the importance of epibenthic invertebrates, scientists seek to identify and explain benthic community patterns, a requirement for documenting or predicting changes. Patterns in species richness, taxonomic and functional composition, abundance and biomass can reveal different types of information and it is, hence, advisable to look into all aspects. For example, epibenthic biomass, distribution and composition can also serve as an indicator for water column conditions and vulnerability to disturbance (Jørgensen *et al*., 2015a). However, part of the variability in epibenthic community structure can be linked to environmental drivers and other abiotic stressors, which will be further delineated in the next section.

So far, a meta-analysis study throughout the Arctic has shown that arthropods, annelids and molluscs are the three most speciose benthic groups (Piepenburg *et al*., 2011). Further, abundance-based surveys of epibenthic distribution reveal a recurring pattern, where mainly echinoderms dominate (Mayer and Piepenburg 1996; Ambrose *et al*., 2001; Bluhm *et al*., 2009; MacDonald *et al*., 2010a). The patchiness of the distribution of these echinoderms, especially ophiuroids, seems to be a pronounced phenomenon across the Arctic. Biomass on the other hand, has a less consistent pattern regarding the dominant phyla. In the Pacific Arctic, high biomass of the arthropod snow crab *Chionoecetes opilio* has been recorded in Chukchi Sea (Bluhm *et al*., 2009), and the ophiuroid *Ophiura sarsii* in the Beaufort Sea (Ravelo *et al*., 2015).

In recent years, and in light of sea ice loss, there has been even more focus on the energy transfer between the pelagic and benthic zones that provides food for benthos (Ambrose and Renaud 1995; Piepenburg *et al*., 1997a; Christiansen *et al*., 2017). Epibenthic invertebrates in the Arctic often rely on food sources coming from the water column, mostly from the euphotic zone (e.g. Boetius *et al*., 2013). Therefore, adaptation of the appropriate feeding strategies are essential for epibenthic invertebrates to survive in an environment where food can be critical on the seafloor. Several epibenthic invertebrates exhibit different feeding strategies to be able to inhabit the specific area without too high intra- or interspecific competition and without too high pressure from the physical stressors. Suspended particles in the water column for example, can advect (horizontal transport) along the seafloor and will, hence, be caught by filter feeding animals (used synonymously here with suspension feeders). Suspension feeders require a habitat with a continuously flow of suspended particles (e.g. narrow straits, locations along shelves, canyons, mouth of fjords) and they tend to aggregate in such areas (Gili and Coma 1998; Grebmeier and Barry 1991). Surface deposit feeding is another remarkable feeding strategy that has shown to be abundant at great depths, but also at soft bottom habitats (Iken *et al.,* 2001; Boetius *et al*., 2013), whereas grazers rely more on primary producers that are found in shallow areas. Consequently, predators are found whenever its prey are found, but do not dominate based on the trophic pyramid (Lindeman 1942). Information about the epibenthic invertebrates' feeding strategies can give indications on habitat conditions or vice versa.

There are many factors involved when trying to explain the distribution of epibenthic invertebrates across the Arctic. Determining which factors are most influential is difficult to ascertain and understand due to the complex interaction between abiotic and biotic processes that are involved (Godbold and Solan 2009). However, it is well known that spatial and temporal patterns in benthic communities are accompanied by gradients in environmental drivers (e.g. hydrography and sediment properties: Mayer and Piepenburg 1996; latitude: Bluhm *et al*., 2009; depth: MacDonald *et al.,* 2010a; Roy *et al*., 2014). Depth is often expressed in several studies as the variable that most explains the changes in community patterns (MacDonald *et al*., 2010a; Buhl-Mortensen *et al.,* 2012; Roy *et al.,* 2014). Nevertheless, depth is considered an indirect factor together with latitude, and a proxy for several environmental variables that vary together with changing depth and latitude (Smith *et al*., 2008; Buhl-Mortensen *et al*., 2012; Roy *et al*., 2014).

Hydrographical features such as temperature, salinity and oxygen content are parameters that can influence the prevalence of species and variability in community structure. Melting sea ice in the Arctic as a result of warming climate, but also seasonal glacial and river run off with endpoint in fjords, creates less saline conditions and makes it difficult for stenohaline organisms to survive since they do not have the ability to osmoregulate (Hickman *et al*., 2014). Seasonal melt water from glaciers and river run offs does not only affect the salinity, but are also influencing the environment with changes in temperature, where for example melting glaciers provide cold water and rivers from mainland can bring warmer water. Furthermore, there has been documented that the ocean temperatures in the Arctic are rising (Comiso *et al*., 2008; Beszczynska-Möller *et al.,* 2012). This limits the prevalence of Arctic species that are adapted to cold environments and creates favorable conditions for sub-Arctic species to inhabit Arctic conditions (e.g. Berge *et al.,* 2005; Grebmeier *et al.,* 2006a). Arctic species has shown to retreat to colder environments in fjords as an acting response to warmer climate (Weslawski *et al.,* 2011).

Physical disturbances are also an important factor that contribute to variability in epibenthic community structure (Gutt *et al.,* 1996; Conlan *et al.,*. 1998; Gutt and Piepenburg 2003). Ice scouring on the seafloor is a particularly common phenomenon in the Arctic (Gutt *et al.,* 1996; Conlan *et al.,* 1998.), which can cause large-scale disturbance for benthic organisms. Both frequent and occasional events of ice scouring in the Arctic can prevent slow-growing, long-lived and sessile species to colonize the seafloor (Gutt *et al.,* 1996; Conlan *et al.,* 1998; Conlan and Kvitek 2005), which can create different epibenthic communities compared to adjacent areas.

In areas where the seafloor is exposed to ice scouring, but also further offshore, ice-rafted drop stones coming from the last ice age and deglaciation of glacial ice can increase small-scale diversity in polar environments (Schulz *et al.,* 2010). Sessile epibenthic invertebrates require hard bottom surface to settle (Tissot *et al*., 2006), and are hence, the reason to small-scale diversities. Seafloor characteristics including sediment grain sizes are important determinants that affect epibenthic communities, but also the structure of the benthic habitats (Feder *et al*., 1994; Mayer and Piepenburg 1996; Piepenburg *et al*., 1997a; Bluhm *et al*., 2009; Buhl-Mortensen *et al*., 2012). In addition to occasional drop stones, sediment characteristics in general can give indications on how strong the currents are influencing the seabed morphology. High current velocity transport away fine sediment with the remaining grains being coarse sediments and large rocks, whereas when there are low current velocities, fine-grained sediment are present. Consequently, the substrate composition will influence epibenthic invertebrate community structure through varied habitat preferences (Snelgrove and Butman 1995). Fine-grained sediment also acts as a sink for organic materials coming from the euphotic zone and can then be a source for carbon (Schulz 2006), which surface deposit feeders and sub-surface deposit feeders can take advantage of.

Export of terrigenous inorganic particles, larger sediment and carbon supply to the benthic realm is another factor that can contribute to variability in community structure. Terrigenous discharges and sedimentation rates are particularly high in the vicinity of river runoffs and melting glaciers (Sylvitski *et al.,* 1989; Holte and Gulliksen 1998; Ashley and Smith 2000; Włodarska-Kowalczuk *et al*., 2005; Renaud *et al.,* 2007; Włodarska-Kowalczuk *et al*., 2012). High turbidity in the water column will reduce primary production and, hence, dilute the amount of organic materials that reaches the seafloor (Görlich *et al.,* 1987). As a consequence of high sedimentation of inorganic particles, bottom-dwelling invertebrates can be buried and filter-feeding organs of suspension feeders can be clogged by too high inorganic sediment load, which results in damage (Moore 1977; Hall 1994). In other words, it is not advantageously to be a filter-feeding organism where there are chances to be buried and clogged.

Water column primary and secondary production, processes and subsequent vertical flux provide organic material to the benthic communities and are an important component that influences community structure in addition to the above outlined physical factors. These events are highly seasonal and a larger proportion sinks to the seafloor in the Arctic (Grebmeier *et al.,* 1995; Wassmann *et al.,* 1996), where benthic production highly reflects processes in the water column (Piepenburg *et al.,* 1997a). High densities and biomasses of benthos in vicinity of the Northeast Water Polynya located on the NEG shelf is one example that there is a tight coupling between pelagic production the benthic realm (Ambrose and Renaud 1995).

Given the characteristic environmental conditions in the different habitats in the study area, epibenthic communities are expected to vary noticeably. The NEG study contains a gradient with typical conditions found in Arctic fjords as glacial inputs towards the steep slope with drastic variations in hydrography, while the Kitikmeot Sea is characterized by a patchwork of areas with high and low (mostly driven) current velocities.

2.3 The two study areas in the Arctic

The Arctic Ocean has a constant advection (horizontal transport) of ocean water from the sub-Arctic that connects sub-Arctic and Arctic water properties. Concurrently, biota from the Pacific Ocean gets advected through the Bering Strait and biota from the Atlantic Ocean is advected through the Barents Sea and Fram Strait (e.g. Berge *et al.,* 2005; Grebmeier *et al.,* 2006a). This connecting conveyor belt of different water masses is also known as the contiguous domains (Carmack and Wassmann 2006; Wassmann *et al.*, 2016). The two study regions that will be in focus in this master's thesis are at the end of the advective contiguous domains, specifically in the outflow areas where water has already spent some time getting modified, and has more Arctic character (Figure 1) (Carmack and Wassmann 2006). The water transport through the CAA is one of the two major outflow shelves where Arctic surface waters connects with Atlantic waters. The other outflow shelf is located in the western Fram Strait and along NEG Shelf (Michel *et al.,* 2006).

2.3.1 Northeast Greenland

Greenland is characterized by spectacular glaciers and fjords that stretch hundreds of kilometers into the mainland, where many of them are the largest fjord systems in the northern hemisphere (Funder *et al.,* 1998). The study area is located where the shelf of Greenland is broadest, in the northeast between longitudes of 20°W - 5°W and latitudes 74°N - 81°N, where it extends more than 300 km from the Northeast Greenland coastline (Arndt *et al.,* 2015) (Figure 2). This region has been almost permanently covered by sea ice throughout the year, hence, used to be difficult to investigate (Laberg *et al.,* 2017). However, in recent years it has been more accessible due to shrinking of the Arctic sea ice (Stroeve *et al.,* 2012).

The Northeast Greenland shelf has a heterogeneous seabed morphology that constitutes of several banks and troughs on the shelf, which stretches further into the mainland often lead to fjord-connecting systems (Laberg *et al.,* 2017). The fjord system in this study, Bessel Fjord has three basins, with the outermost basin being the deepest (Figure 2). The fjord is surrounded by glaciers, where the known Soranerbræen glacier (Seale *et al.,* 2011) extends into the sea (pers. obs.). These geomorphological features in the region are traces from the last glacial maximum (Laberg *et al.,* 2017) and create a heterogeneous habitat for benthic organisms to settle. For all fjords that are connected to glaciers, a common phenomenon is high sedimentation (Görlich *et al.,* 1987; Sylvitski *et al.,* 1989; Ashley and Smith 2000). In addition, the shallowest parts in an ice covered fjord can expose the seabed to ice scouring (Gutt *et al.,* 1996; Conlan *et al*., 1998; Conlan and Kvitek 2005), which makes it difficult for sessile organisms to settle and cope with.

The Arctic character of the NEG coast and shelf is created by outflow of Arctic waters (Michel *et al.,* 2015) that pass through the western Fram Strait, transported by the Transpolar Drift (Kwok 2008). These Arctic water masses form the East Greenland Current (EGC) that flows further south (Hopkins 1991; Sejr *et al.,*. 2017) along the NEG continental shelf. Branches of Atlantic water coming from the West Spitzbergen Current (WSC) cross Fram Strait, and converge with the EGC. These Atlantic water branches along shelf break and slope transport organic surplus and create warmer and more saline conditions compared to local surrounding waters, along the continental shelf break and slope in Greenland Sea (Schneider and Budéus 1997). There has also been evidence of "old" water of Pacific origin that has exited through the Fram Strait (Jones *et al.,* 2003).

On the NEG shelf during spring and summer, there are recurring ice-free areas in the pack ice, which is known as the Northeast Water Polynya (NEW) (Schneider and Budéus 1997). This creates opportunities for potential phytoplankton blooms, which will thereafter provide a surplus to the benthic communities as it sinks (Ambrose and Renaud 1995; Piepenburg *et al.,*. 1997a). During the warmer periods from spring to fall, glacial ice melting contributes to large amounts of fresh water that are transported into the marine systems. Also, a large contributor to freshening of the coastal waters in NEG (Sejr *et al.,* 2017) is the shrinking Greenland ice sheet in the northeast (Evans *et al.,* 2009; Khan *et al.,* 2014). Melting processes enrich the areas in vicinity to the glaciers with terrigenous sediment supply (Straneo *et al*., 2011).

*2.3.2 **The Kitikmeot Sea region***

The Canadian Arctic Archipelago consists of narrow channels and interconnecting basins and sills that are traces of glacial activity from the past (Michel *et al.,* 2006), where the Kitikmeot Sea is also a part of these traces from the past. The Kitikmeot Sea is a region located in the province of Nunavut in the southern CAA and encompasses Coronation Gulf, Bathurst Inlet and Queen Maud Gulf (Figure 3). The name Kitikmeot Region itself has so far not been frequently used in the oceanographic literature, but is one of the three census divisions of Nunavut in the CAA. This area has recently been more often mentioned in scientific studies since the new Canadian High Arctic Research Station in the regional seat Cambridge Bay has been established in response to the increased attention the region receives through its location in the increasingly navigable Northwest Passage.

The Coronation Gulf is connected to Queen Maud Gulf by the shallow Dease Strait (Carmack and McLaughlin 2011), where most of the stations from this study lie. Further south in the study region is Bathurst Inlet and consists of many islands and narrow passages in-between (B.A. Bluhm, UiT – The Arctic University of Norway, Tromsø, pers. comm.). Several rivers also flow into Bathurst inlet (Carmack and McLaughlin 2011). The largest rivers in the Kitikmeot Sea region that influences the marine environment is the Coppermine River that terminates in Coronation Gulf (outside the study area), whereas the Burnside River and Hood River terminate in Bathurst Inlet (Carmack and McLaughlin 2011) (Figure 3). Additionally, the region is also influenced by relatively fresh oceanic water that originates from the Pacific (Codispoti and Owens 1975; McLaughlin *et al.,* 2002; Jones *et al.,* 2003). The freshwater in the Kitikmeot Sea creates a highly stratified water column resulting in rather low nutrient concentrations in the surface waters, coincident with generally low rates of primary production (C.J. Mundy, University of Manitoba, pers. comm.). Mostly, nutrients are trapped under a sharp pycnocline, but high speed of water flow through narrow passages and over sills initiates vertical mixing in these locations. This mixing facilitates primary production in the water column and results in a higher saturation level of oxygen and chlorophyll compared to the non-mixed areas in the region (Carmack and McLaughlin 2011).

Shallow sills in the CAA prevent dense oceanic water with Atlantic origin to enter the Coronation Gulf and further east in the Canadian Archipelago (Carmack and McLaughlin 2011). In the narrow straits in Bathurst Inlet, food particles and finer sediment are drifting away while coarser sediment remains on the bottom. In contrast, slowing tidal currents downstream from such passages allow these advected finer sediment and particles from the upper layers to fall to the sea floor.

So far, few benthic studies have been done in the CAA (e.g. Dale, 1989; Brown *et al.,* 2011; Roy *et al.,* 2014; Marmen *et al.,* 2017), and these were not conducted exactly in the same area. This study is the first that presents results and benthic taxonomic descriptions from the Kitikmeot Sea.

2.4 Objectives of the studies

Given the scarcity of knowledge on epibenthic communities in the two poorly studied regions of the Arctic, this study aims to describe epibenthic communities and the structure in relation to gradients in environmental conditions. The following questions in this master's thesis were therefore asked to provide a better understanding of the two poorly studied regions:

(1) *Does epibenthic community structure differ across habitats within each of two poorly studied Arctic regions?*

Question 1 is addressed by the following objectives: describe epibenthic communities in Northeast Greenland (NEG) waters from an inner fjord towards the shelf break and upper continental slope from trawl samples collected during TUNU-VI (2015) and TUNU-VII (2017) expeditions and to describe epibenthic communities in the Kitikmeot Sea in the Northwest Passage, from photographic transects in areas of different current regimes.

(2) *Do collected environmental variables within these areas explain epibenthic community structure in these two Arctic regions?*

Question 2 is addressed by the following objectives: identify to what degree environmental gradients in seabed and hydrographic properties across the NEG study area from fjord to upper slope explain part of the patterns in community structure and see if taxonomic and functional community composition (specifically feeding type) in the Kitikmeot Sea region differs in different current regimes.

This study also helps create baseline information on the scarcely investigated areas in NEG and Northwest Passage waters that so far have been difficult to access. Also, it will increase our understanding of an Arctic that undergoes rapid changes in the marine ecosystems.

3 Materials and methods

3.1 Northeast Greenland (NEG)

*3.1.1 **Field sampling in Northeast Greenland***

Sampling of epibenthic invertebrates was performed as part of the TUNU Programme (Christiansen 2012). The TUNU Programme is an ongoing research programme that has been performed since 2002, where the main focus has been to address the diversity, population structure and distribution of marine fishes in Northeast Greenland waters. The term TUNU refers to the geographical area of NEG and originates from the Greenlandic language (Christiansen 2012) and is, hence, used as a name for the NEG expeditions. It is only recently that comprehensive sample collection of epibenthic invertebrates has been included in the TUNU Programme (TUNU-VI in 2015 and TUNU-VII in 2017), which is the main focus in this part of the thesis. The first sampling of benthic invertebrates was conducted during the TUNU-VI expedition (8 – 15 August) in 2015. Because of intense sea ice coverage along the coast of NEG in 2015, sampling took place at the ice-free shelf-break and slope at depths from 177 to 1011m (Table 1). Additional sampling was conducted two years later during the TUNU VII expedition (14 – 26 September) in 2017 at depths from 65 to 484 m (Table 1). Low sea ice cover in NEG waters at that time allowed sampling nearshore in Bessel Fjord and adjacent areas including Dove Bugt, Belgica Bank, another shallow bank along 76 °N latitude and other locations on the shelf (Table 1, Figure 2). Sampling for both years was conducted from R/V Helmer Hanssen (UiT – The Arctic University of Norway, Tromsø). Each specific location during the TUNU expeditions contained several operations where sampling of sediment, water column, and benthic and pelagic organisms were performed. For every new gear used in an operation, a unique station number was provided to avoid confusions during sampling. A station is, therefore, referred to as one gear deployment, whereas a location consisted mostly of two gear deployments, which was Campelen 1800 shrimp trawl (hereafter referred as Campelen trawl) and an Agassiz trawl (Agassiz 1888). However, three locations had only one gear deployment of Campelen trawl. During this period, 33 stations (i.e. one gear deployment = one station) from 18 locations were sampled between latitudes 74.55 to 79.27 °N and longitudes 5.22 to 21.72 °W (Figure 2). Fifteen locations sampled epibenthic invertebrates from both Campelen trawl and Agassiz trawls, whereas the three remaining locations collected epibenthos with Campelen trawls only. In order to increase spatial coverage of the study area, both years were therefore included in the statistical analysis.

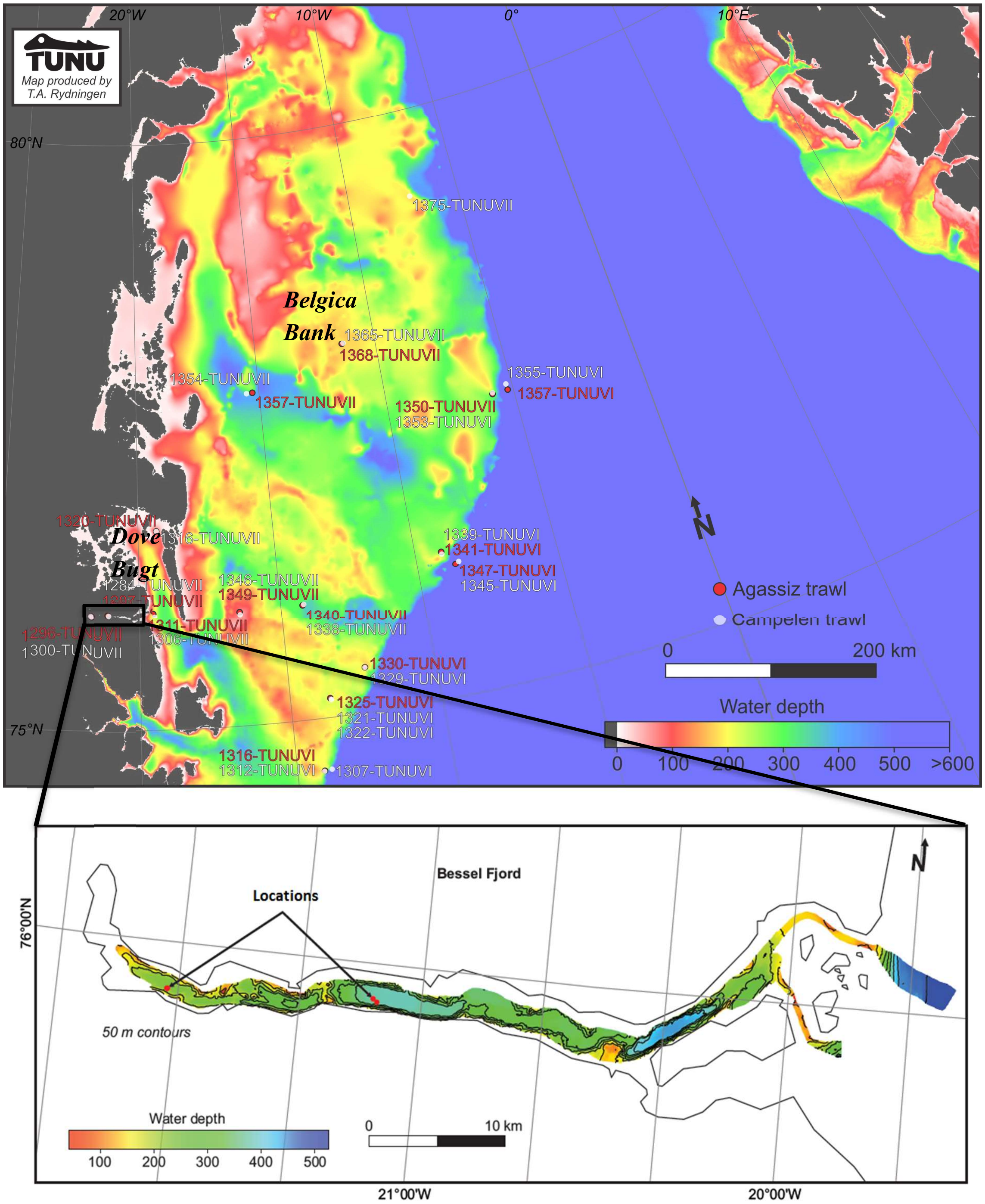


Figure 2: An overview of the epibenthic stations that were visited during TUNU-VI and TUNU-VII expeditions to Northeast Greenland in 2015 and 2017, respectively. This map shows both Campelen 1800 Shrimp trawl and Agassiz trawl stations, which were mostly deployed at the same locations. Additional map below is an enlargement of Bessel Fjord, which shows the locations that were visited in september 2017.

Table 1: Station table for when TUNU-VI and TUNU-VII expeditions took place in North East Greenland waters in 2015 and 2017, respectively. The stations are listed in chronological order when sampled. Sampling took place at 18 different locations, hence the grey and white color for rows to see the total catch of taxa at the specific location. Abundance and biomass were only calculated for Campelen 1800 Shrimp trawl, but biomass were not evaluated during TUNU-VI (therefore NA = Not Applicable). NA's also applied for chlorophyll *a* and percentage sand and percentage mud from 2015.

Station	Date	Start depth (m)	Latitude °N	Longitude °E	Gear	Habitat type (communities)	Abundance no. of ind. per 1000 m^2	Biomass g ww per 1000 m^2	No. of taxa	No. of taxa for both gears in same location (no overlap)	Bottom temp (°C)	Bottom salinity (PSU)	Turbidity measured [FTU]	Bottom oxygen (ml/l)	Integrated chl a (mg/m^2)	% Sand	% Mud
1307-TUNUVI	08.08.2015	969	74.56	-13.90	Campelen	Slope	10.8	NA	8	8	-0.16	34.91	0.06	5.73	NA	NA	NA
1312-TUNUVI	09.08.2015	299	74.55	-14.14	Campelen	Shelfbreak	37.27	NA	23	50	1.78	34.98	0.06	5.75	NA	NA	NA
1316-TUNUVI	09.08.2015	316	74.55	-14.13	Agassiz	Shelf break	NA	NA	36		1.78	34.98	0.06	5.75	NA	NA	NA
1321-TUNUVI	10.08.2015	213	75.15	-13.64	Campelen	Shelf break	7.9	NA	32	32	1.14	34.9	0.15	5.63	NA	NA	NA
1322-TUNUVI	10.08.2015	211	75.15	-13.64	Campelen	Shelf break	4.1	NA	18	32	1.14	34.9	0.15	5.63	NA	NA	NA
1325-TUNUVI	10.08.2015	212	75.16	-13.68	Agassiz	Shelf break	NA	NA	23		0.14	34.9	0.06	5.69	NA	NA	NA
1329-TUNUVI	11.08.2015	177	75.38	-12.39	Campelen	Shelf break	4.6	NA	22	33	1.33	34.9	0.11	5.65	NA	NA	NA
1330-TUNUVI	11.08.2015	177	75.39	-12.39	Agassiz	Shelf break	NA	NA	20		1.33	34.9	0.11	5.65	NA	NA	NA
1339-TUNUVI	12.08.2015	280	76.25	-9.05	Campelen	Shelf break	9.3	NA	15	37	1.59	34.94	0.15	5.52	NA	NA	NA
1341-TUNUVI	12.08.2015	281	76.27	-9.06	Agassiz	Shelf break	NA	NA	33		1.59	34.94	0.15	5.52	NA	NA	NA
1345-TUNUVI	13.08.2015	980	76.16	-8.52	Campelen	Slope	6.9	NA	13	46	-0.17	34.91	0.06	5.68	NA	NA	NA
1347-TUNUVI	13.08.2015	937	76.14	-8.65	Agassiz	Slope	NA	NA	39		-0.17	34.91	0.06	5.68	NA	NA	NA
1355-TUNUVI	14.08.2015	1011	77.52	-5.23	Campelen	Slope	6.4	NA	8	17	-0.11	34.9	0.06	5.66	NA	NA	NA
1357-TUNUVI	14.08.2015	994	77.47	-5.22	Agassiz	Slope	NA	NA	9		-0.11	34.9	0.06	5.66	NA	NA	NA
1353-TUNUVI	14.08.2015	385	77.48	-5.83	Campelen	Shelf break	6.7	NA	13	41	0.35	34.89	0.06	5.64	NA	NA	NA
1350-TUNUVI	14.08.2015	375	77.47	-5.84	Agassiz	Shelf break	NA	NA	32		0.35	34.89	0.06	5.64	NA	NA	NA
1284-TUNUVII	17.09.2017	380	75.98	-21.09	Campelen	Fjord	16.2	103.0	24	42	-1.43	33.51	0.49	6.75	24.69	7.74	92.26
1287-TUNUVII	17.09.2017	377	75.98	-21.13	Agassiz	Fjord	NA	NA	35		-1.43	33.51	0.49	6.75	24.69	7.74	92.26
1296-TUNUVII	17.09.2017	237	75.97	-21.70	Agassiz	Fjord	NA	NA	30	46	-1.48	33.44	0.26	6.76	19.51	16.40	83.60
1300-TUNUVII	18.09.2017	235	75.97	-21.72	Campelen	Fjord	10.6	65.0	23		-1.48	33.44	0.26	6.76	19.51	16.40	83.60
1306-TUNUVII	18.09.2017	481	75.99	-19.46	Campelen	Fjord	6.8	118.7	24	46	1.57	34.86	0.38	6.01	27.72	8.88	91.12
1311-TUNUVII	19.09.2017	484	76.02	-19.51	Agassiz	Fjord	NA	NA	37		1.57	34.86	0.38	6.01	27.72	8.88	91.12
1316-TUNUVII	19.09.2017	213	76.72	-19.32	Campelen	Shelf	39.6	527.7	43	52	1.23	34.66	0.18	6.43	17.57	7.61	93.29
1320-TUNUVII	19.09.2017	215	76.72	-19.32	Agassiz	Shelf	NA	NA	11		1.23	34.66	0.18	6.43	17.57	7.61	93.29
1338-TUNUVII	21.09.2017	350	76.01	-14.19	Campelen	Shelf	38.3	250.0	28	46	1.12	34.83	0.25	6.51	21.23	1.76	98.24
1340-TUNUVII	21.09.2017	343	76.00	-14.23	Agassiz	Shelf	NA	NA	36		1.12	34.83	0.25	6.51	21.23	1.76	98.24
1346-TUNUVII	21.09.2017	65	75.97	-16.45	Campelen	Shelf	854.1	374.2	47	58	-1.63	32.52	0.51	7.85	45.68	1.03	98.97
1349-TUNUVII	21.09.2017	68	75.99	-16.46	Agassiz	Shelf	NA	NA	26		-1.63	32.52	0.51	7.85	45.68	1.03	98.97
1354-TUNUVII	22.09.2017	404	77.84	-15.51	Campelen	Shelf	36.5	133.7	38	41	1.54	34.85	0.15	6.24	18.99	too rocky	too rocky
1357-TUNUVII	22.09.2017	440	77.84	-15.27	Agassiz	Shelf	NA	NA	8		1.54	34.85	0.15	6.24	18.99	too rocky	too rocky
1365-TUNUVII	23.09.2017	182	78.16	-11.31	Campelen	Shelf	64.0	356.0	66	88	-0.01	34.31	0.12	6.61	20.67	12.04	87.96
1368-TUNUVII	23.09.2017	175	78.16	-11.37	Agassiz	Shelf	NA	NA	51		-0.01	34.31	0.12	6.61	20.67	12.04	87.96
1375-TUNUVII	24.09.2017	265	79.27	-7.19	Campelen	Shelf break	27.5	148.4	34	34	1.00	34.8	0.14	6.39	19.99	11.02	88.97

3.1.2 Sampling gears used to collect epibenthos

During both expeditions, a Campelen trawl and an Agassiz trawl were used to collect epibenthic invertebrates. The Campelen trawl is rigged with a 35.6 m rock-hopper with rubber disks of 356 mm in diameter, attached to the ground gear (Walsh and McCallum 1997). The trawl is made of polyethylene twines that are 4.0, 3.0 and 2.0 mm in diameter and are woven to make a mesh size that varies from 80 mm in the wings to 60 mm and 40 mm in the cod end (Walsh and McCallum 1997). This arrangement allows capture and retention of the smaller fishes and the large benthic invertebrates. The calculated swept area for this case study is based on a fixed width of the trawl opening of 11.7 m in accordance with the calculations used by the Institute of Marine Research (IMR) for their snow crab assessments (Carsten Hvingel, Institute of Marine Reasearch, pers. comm.). For fishes, a SCANMAR hydroacoustic instrumentation sensor was attached to the trawl doors and at the upper part of the net where it recorded the trawl opening dimensions (horizontally) during trawling time at the bottom. This can provide an estimate of trawling area when tow duration and speed of the boat is known (see section *3.1.4 Data analyses* for the calculations). Target towing duration of the trawl was set to approximately 15 minutes at the bottom, but in fact varied from 10 to 29 minutes and was determined by the SCANMAR sensor. Towing speed was approximately three knots for both years. The trawled area of the seafloor for each station was subsequently estimated and epibenthos counts and weights were standardized to 1000 m^2 to allow comparison between locations. This was only done for the Campelen 1800 Shrimp trawl since tow duration at the bottom was known and the width was set. Even if this approach contains some errors, it is a standard scientific semi-quantitative method to estimate epifaunal densities in benthic ecology (Eleftheriou and MacIntyre 2005) and fisheries assessments (Havforskningsinstituttet 2008; Jørgensen *et al*., 2015a; Jørgensen *et al.,* 2015b)

In contrast to the Campelen trawl, the Agassiz trawl is a qualitative sampling tool used to collect epifaunal organisms (Eleftheriou and MacIntyre 2005). Therefore, all Agassiz trawl stations were not used for multivariate statistics, but were instead included in the determination of number of taxa and relative composition. The width and height of the Agassiz trawl was manually measured to be 1.80 m and 0.47 m, respectively. The length of the trawl was 2.78 m and the trawl's mesh size was 80 x 80 mm throughout the net. The trawl was equipped with a metal frame for giving a fixed size of the trawl mouth. A heavy metal frame ensures that the trawl stays on the seafloor when trawling, but it can still jump occasionally depending on seafloor topography and sediment substrate (J.S. Christiansen, UiT – The Arctic University of

Norway, Tromsø, pers. comm.). Towing duration of the Agassiz trawl for both cruises varied between 9 and 40 min with a speed of 0.7 to 3.7 knots.

Once trawls were hauled on deck, the catch from the Campelen trawl was further transported to the fish lab, whereas the catch from Agassiz trawl remained on deck for washing and sorted on a sorting table. In few cases, a sub-sample was taken from the well-mixed haul when the trawls had too large numbers of organisms to be sorted. Epibenthic invertebrates were then separated from fishes and sorted to the lowest possible taxonomic level practical in the field, and thereafter counted by each putative species. All unaccepted and synonymized taxa names that were identified were updated in the World Register of Marine Species (WoRMS) by using the taxon match tool (www.marinespecies.org , [Accessed: 09.03.2018]). Gram wet weight (g ww) was determined with electronic scales (Marel M2200) for the TUNU VII expedition (2017) only, due to time constraints on TUNU-VI in 2015. Organisms that were heavier than 200 g in total (e.g. *Gorgoncephalus* spp., *Umbellula encrinus, Molpadia borealis*) were weighed on the scales in the fish lab onboard. For colonial organisms such as bryozoans, cnidarians, hydrozoans and poriferans, only weights were recorded, since individuals cannot be enumerated. Many organisms were identified to species level onboard, but organisms with unknown species level were provided a descriptive name for later identification in the lab at university when more identification keys and taxonomic expertise were available. For that purpose, voucher specimens were preserved in a 4% seawater-formaldehyde solution for fixation of tissue. Thereafter, the voucher specimens were transferred to 70% ethanol in the lab for long-term storage and transportation to taxonomic experts.

The TUNU-group acknowledges that the lack of expertise and region-specific identification keys for specimens from some phyla (e.g. Brachiopoda, Bryozoa, Cephalorhyncha, Cnidaria, Nemertea, Porifera and Sipuncula) made it difficult to identify these groups. These taxa were therefore, given a higher taxonomical level than species level. Consequently, the term taxon richness is more precise in this context than species richness. In addition, I know at least for the TUNU-VII Expedition (where I participated in the fieldwork) that some specimens were not consistently separated to correct species level and therefore they were given a higher taxonomic rank. This applied for example to several species within the species-rich gastropod genera *Colus* and *Buccinum*, and therefore I combined the specimens to genus level. This also applied to some Amphipoda, and they were then given a higher taxonomical rank. Taxonomic identification of fixed voucher specimens by experts (see Acknowledgements) enabled a higher taxonomic resolution for estimating taxon richness at the regional level and for the community analysis for both years. Yet, taxonomic identification by experts are still ongoing for subsets of taxa in the taxonomic ranks Cnidaria, Mollusca, Polychaeta, Porifera, Pycnogonida and Sipuncula.

3.1.3 ***Environmental parameters***

From each location of the 2017 cruise, I compiled nine different environmental parameters (temperature, salinity, turbidity, bottom oxygen, chlorophyll *a* (Chl *a*), sediment properties as percentage sand and percentage mud and spatial gradients as latitude and depth). Environmental parameters for the community analysis in this study were chosen in accordance to answer this thesis' research questions.

Environmental hydrographic variables closest to the seafloor (e.g. temperature, salinity, oxygen and turbidity) were extracted from CTD casts performed by the Sea-Bird Electronics SBE-911 conductivity-temperature-depth (CTD) profiler. CTD casts were performed in the vicinity of where the trawls were conducted for closest reliable environmental values of the seafloor. Chlorophyll *a* content in the water column was measured from water column samples taken with a CTD-rosette at distinct depths by phytoplankton experts onboard using standard methodology (S. Kristiansen, UiT – The Arctic University of Norway, Tromsø, pers. comm.). In this case, the integrated chlorophyll *a* (mg/m^2) value in the entire water column was used as an indirect source of food to the benthic communities. This was calculated by the trapezoidal integration rule.

Sediment samples were collected from every box core at each location in 2017 so sediment grain size analysis could be performed by staff at the Department of Geosciences at The Arctic University of Norway, Tromsø. Exceptionally, box core from the location where stations 1354-TUNUVII and 1357-TUNUVII occurred, failed to sample because of too rocky habitat, hence, no sediments were available. The grain sizes were analyzed with Beckman Coulter Paricle Size analyzer LS 13320 where they were treated with HCl and H_2O_2 to remove organic material and calcium carbonate. Substrate type from the locations give indications on how strong the currents are influencing the seabed morphology. Epibenthic invertebrate habitat preferences can also be related to sediment type (Snelgrove and Butman, 1995). The geologists onboard also collected bathymetric information by the Multi-beam echo sounder system and used this to visualize where the sills, and where banks and troughs were positioned in the study region. Data gathered by the Multi-beam echo sounder system enabled a representative visualization of the bathymetry and are valuable to interpret habitat conditions.

3.1.4 Data analyses

The trawling distance in meter was calculated with the following equation:

(1)

$$Mean\ speed\ (kn) * 1852\ m * \frac{1}{60} * traling\ time\ in\ \mathrm{min} =$$

$$trawling\ distance\ in\ meter$$

Traling distance in meter was then multiplied with the fixed opening of the trawl of 11.7 m and then the swept area was calculated. Comparison between Campelen stations was feasible when standardization of abundance (no. ind per 1000 m^2) and biomass (g ww per 1000 m^2) to a defined area was performed:

(2)

$$\left(\frac{No.\ of\ ind\ or\ gram\ wet\ weight\ \ in\ specific\ taxon}{swept\ area\ (m^2)}\right) * 1000\ .$$

Question 1

Univariate community composition data plot visualization was performed with the statistical software R (version 3.3.3. “Another Canoe”) and by using the additional software packages “ggplot2”, “reshape2”, gridExtra”, and “scales” and Microsoft Excel 2016. From the Agassiz trawl hauls only taxa richness and relative composition by count and weight were included in data analyses. The station map was made in Global Mapper and CorelDRAW by geologists at UiT (see Acknowledgements). Maps depicting taxa richness, abundance and biomass estimates as scaled circles were made in ArcMap 10.5 by using Jenks’ natural breaks function. Multivariate analysis of community composition for Campelen stations from both years was performed in the statistical software program PRIMER v. 7.0.13, where abundance-based analyses were the main focus.

For the multivariate statistics, a Q-type analysis was performed to see if any groups formed similar biotic composition (Johnson and Barmuta 2015). Fourth-root transformation of abundance and biomass was used in this study to even out the influence of dominant species and given the many zeros in the data set (Field *et al.,* 1982; Clarke and Warwick 2001; Johnson and Barmuta 2015). Similarities between the taxa and stations were computed by using the Bray-Curtis Coefficient (Bray and Curtis 1957). This similarity coefficient is frequently used in ecology since it has its advantages to take into account that stations or groups are not necessarily biologically similar even if they all are lacking the same taxon (Legendre and Legendre 1998; Johnson and Barmuta 2015). Stations with similar taxa assemblages formed groups and were depicted in a dendrogram using Hierarchical Cluster Analysis (HCA) with group average sorting and also as non-metric multidimensional scaling (nMDS) plots (Kruskal and Wish 1978). This was to present patterns in community structure. Groups formed in HCA and in nMDS were hence given the term "communities" and "habitat type" due to similar geographical features. Testing the validity of the clusters in group average sorting for the HCA was performed by Similarity of Profile Analysis (SIMPROF) test with $\alpha = 0.05$. Appearance of red dotted lines in the dendrogram indicated that the clusters are not statistically significant different. Analysis of Similarities (ANOSIM) was used to test if gear types and *a priori* determined habitat type were statistically significant (Clarke and Warwick 2001). To detect which taxa contributed the most to the separation of communities in nMDS and in HCA a similarity of percentages (SIMPER) routine was performed.

Question 2

To identify the combination of environmental parameters that best correlates with the biological pattern in community structure, Biological- Environmental interactions (BIO-ENV) was used. Inconsistent sampling of environmental parameters between the two TUNU expeditions resulted in separate analyses for BIO-ENV, one for the combined two cruises containing less explanatory variables (water depth, latitude, bottom temperature, bottom oxygen, bottom salinity and turbidity). The other BIO-ENV was conducted only for 2017 only containing additional environmental variables to identify if a more extensive data set could reveal other correlations with the biological parameters (integrated chlorophyll *a*, percentage of sand and percentage of mud). The included environmental variables were normalized and correlated with the biological variables based on the ranks of similarities using a Euclidian distance matrix for environmental variables and Bray-Curtis similarity matrix for biological variables (i.e. the taxa). Some stations in the study region had missing values for environmental variables, and they were, therefore, either given the mean value of all, which implied for the sediment grain size at station TUNUVII-1354 (Table 1). Principal Component Analysis (PCA) was performed as an additional ordination technique to see if the environmental variables provided same pattern in the community as the biological variables. PCA was performed on normalized environmental variables for the six environmental variables that was collected for both years. In addition, PCA is preserving the information in the data set, where it uses the most important dimensions to explain the multivariate information that are present (Johnson and Barmuta 2015).

3.2 The Kitikmeot Sea, Canadian Arctic Archipelago

3.2.1 Study region and field sampling

The study was performed in the Kitikmeot Sea in the Canadian Region Nunavut between latitudes from 66.93 to 69.03 °N and longitudes from 105.85 to 108.23 °W (Figure 3), and took place during August 11 - 15 in 2016 onboard R/V Martin Bergmann. Seafloor images were collected at five different localities (Algak Passage, Tinney Gate, and Marcet Minch in Bathurst Inlet, and Turnagain Point and the Finlayson Islands in Dease Strait connecting Coronation Gulf and Queen Maud Gulf) (Table 2, Figure 3). From the five localities, seven stations (two stations from Algak Passage, one from Tinney Gate, one from Turnagain Point and three stations from Finlayson Islands) were used for image analysis with a depth that varied between 20 – 93 m (Table 2, Figure 3). One location was excluded from the image analysis (Marcet Minch) because high current velocities resulted in very blurred images. Drift speed of the vessel when photos were taken varied from 0.1 – 1.25 kn (Table 2) depending on the surface currents, tidal cycle and wind speed. Benthic invertebrates collected by a dredge and a van Veen Grab were used as support materials to improve taxonomic resolution in the images. Organisms caught by van Veen Grab are listed in Appendix Table 1. The van Veen grab (Wilco, 0.1 m^2) was used at soft bottom locations to collect sediment samples, macrofauna and small epifaunal invertebrates. Benthic invertebrates caught in the grab were washed onboard in sieves of 2 mm and 0.5 mm mesh size. Also, a small dredge was used to collect epibenthic invertebrates at hard bottom sites and taxa caught can be seen in Appendix Table 2. The dredge equipment had a measured width of 55 cm, height of 25 cm and length of the mesh bag of 80 cm with a mesh size of 10 mm. Additional weights in form of metal chains of approximately 4 kg were added to the frame of the dredge for better bottom contact. Bottom time of the dredge ranged from three to six minutes. Haul speed depended on drift speed of the vessel and ranged from < 0.1 to > 1 knots.

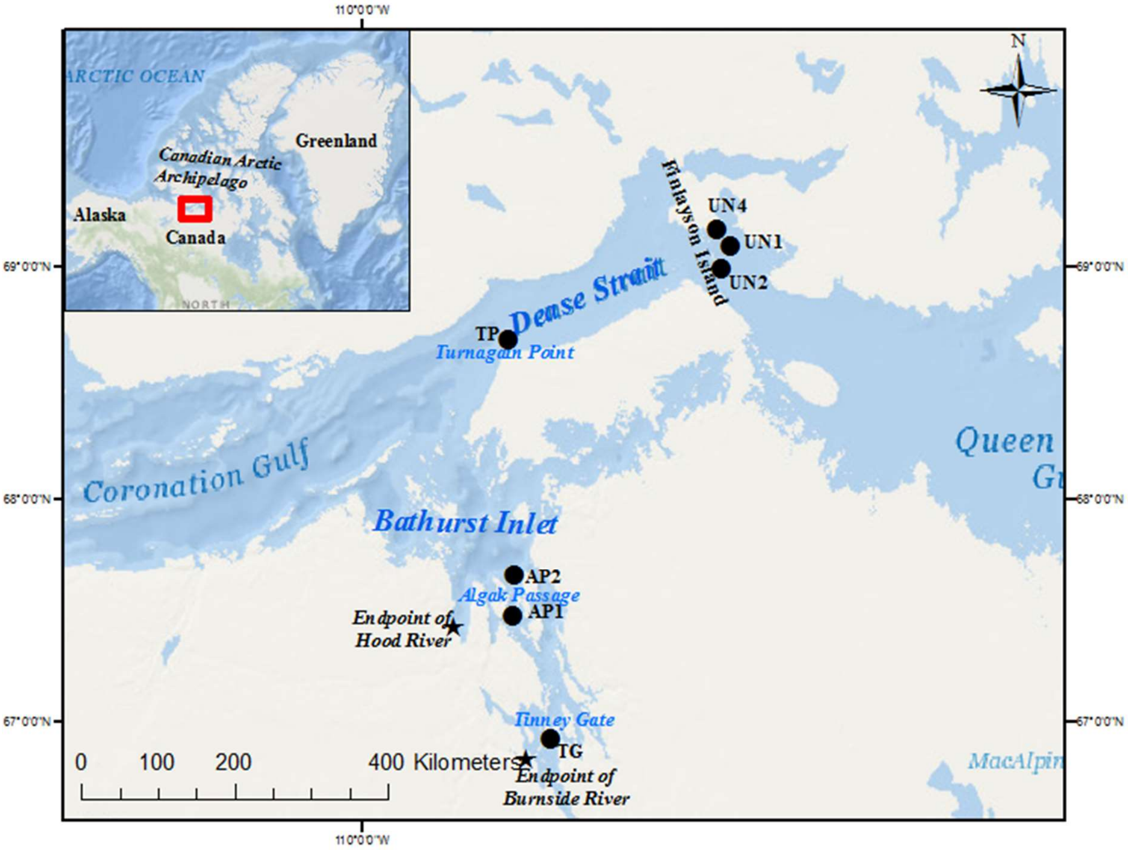


Figure 3: Overview of the seven stations used for imagery analysis that were visited in the Kitikmeot Sea in August 2016.

Table 2: Stations that were sampled for image analysis in the Kitikmeot Sea, Canadian Arctic Archipelago in 2016 on R/V Martin Bergmann. Stations are sorted in chronological order . Environmental variables collected in the vicinity was bottom temperature, salinity, turbidity and oxygen. Table also lists mean abundance per m^2, number of taxa (no. of taxa) abundance range, number of images analysed at each station. Standard deviation (S.D) of mean area per m^2 is also shown.

Station	Location	Date	Latitude °N	Longitude °E	Depth m (start)	Drift speed (kn)	Near bottom temp (°C)	Salinity	Sediment grain size	Current velocity	Turbidity	Oxygen ml/l	Mean abundance no. of ind. per m^2	No. of taxa	Abundance range no. of ind. per m^2	No. of images analyzed in transect	Mean area per image (m$^{2)}$	Standard devitation (S.D) of mean area per image (m$^{2)}$
TP	Turnagain Point	11.08.2016	68.69	-108.27	30	0.6 (from dregde obs)	1.33	27.46	Hard	High flow	0.26	8.26	16.0	17	4.4 - 31.7	30	2.59	0.62
TG	Tinney Gate	13.08.2016	66.92	-107.78	17	1.25	-0.19	27.70	Intermediate / mix	Transitional site	0.23	6.10	4.6	13	1.1 - 11.6	29	1.18	1.48
AP1	Algak Passage	14.08.2016	67.57	-108.23	75	0.1	-0.86	28.27	Soft	Low flow	0.18	7.24	40.7	12	17.7 - 70.2	30	0.30	0.06
AP2	Algak Passage	14.08.2016	67.58	-108.23	93	< 0.1	-0.86	28.27	Soft	Low flow	0.18	7.24	208.7	11	97.6 - 330.0	30	0.19	0.09
UN1	Finlayson Island	16.08.2016	69.00	-105.86	20	1	0.58	28.85	Hard	High flow	0.17	8.26	43.5	22	16.0 - 101.2	30	0.85	0.53
UN2	Finlayson Island	16.08.2016	69.00	-105.85	42	0.5	-0.20	28.69	Hard	High flow	0.12	8.33	5.7	11	0.85- 30.0	28	2.34	0.98
UN4	Finlayson Island	16.08.2016	69.06	-105.85	47	0.5	-0.20	28.69	Intermediate / mix	Transitional site	0.12	8.33	22.2	13	14.1 - 62.6	25	1.16	0.48

3.2.2 Image collection, processing and analysis

Still photos for the image analysis were taken with a downward-facing Gopro Hero 4 silver. Photos were taken with an interval of every 10 second for a duration of an approximately 15 minutes long transect at each station. Original Gopro camera housings are waterproof to a depth of 40 meters. To be able to use the camera deeper than this, the camera was equipped with a different housing. The camera and the housing were mounted on a metal frame, where a light source (conventional SCUBA dive light) and two lasers were attached. The two laser pointers were positioned in the middle of the picture with a distance of 19 cm, which made it possible to calculate the area of every photo that was analyzed. The distance of the camera from the seafloor was aimed to be between 1 - 2 m above the seafloor. This distance was adjusted manually with a wire where the camera was affixed to and could be controlled visually by a small video camera screen with live feed. Sudden changes in water depth, current velocity and the occurrence of cobble and boulders along the transects resulted in variation in the distance from seafloor and, hence, the area imaged which varied from 0.10 m^2 to 7.13 m^2 for all stations.

The camera captured between 57 – 139 pictures from each station. The selection of the sub-set of images analyzed was based on image quality. To assess the quality of the images analyzed, some criteria were applied to allow a precise and consistent quantification of organisms on the seafloor as possible. Some images were considered as ineligible and excluded from the analysis based on the following criterias; if pictures that were too bright so that the laser points were invisible, photos with too high turbidity, so the seafloor could not be seen, and also, photos where one laser pointer was not on the seafloor were excluded. This was to minimize the bias during the image analysis. After sorting out the images that could be included in the analysis, a sub-selection was then randomly chosen by www.numbergenerator.org to reduce the pool of photos to an amount that was both considered representative of the area and manageable for this thesis. A goal of thirty images for each station was set for this study to analyze, but in some cases the number was lower (25 images for station UN4, 28 images for UN2 and 29 images for station TG) due to the criterias mentioned above. On many occasions, subsequent images overlapped at some stations with low current velocity (i.e. AP1 and AP2). Therefore, overlapping photographs were not analyzed to prevent double counting of organisms present on images.

Photos were affected by the fish eye effect of the GoPro lens and will give wrong estimates of the area in the pictures when the distorted edges are included. Therefore, every picture used for image analysis was cropped to show the center of the image with the laser pointers positioned as close to the middle of the image as possible. Cropping varied depending on how strong the fish eye effect was in the corners of the photos, but it was attempted to keep the level of distortion consistently low based on visual assessment (Table 2). The dive light produced a light cone that did not illuminate the entire image evenly, which made it difficult to quantify the percentage cover of the coralline red algae. Instead, they were recorded as “present” or “absent”. Area in the photo was calculated using the program Image J by knowing the exact number of pixels between the laser pointers that had a fixed distance of 19 cm.

Individuals and colonies of all taxa were counted and counts on the images were standardized to an area of 1 m^2. There were some doubtful cases were the specimens on the images were difficult to identify. Therefore, determination of taxa on the images was supported by voucher specimens that were caught in the dredge trawl and in the van Veen Grab (Appendix Table 1, Appendix Table 2). After one round of image analysis, images were analyzed one more time to even out learning effects during the analysis. Organisms that still could not be identified were given a higher taxonomic rank. Organisms that were too difficult to identify on the images, were given a descriptive name with “morphotype” and the name of the taxon that had similar morphological features. Polychaeta tubes that were clearly sticking out of the sediment were counted and included in the analysis, but the proportion of living organisms remains unknown. Other studies have considered Polychaeta tubes as habitat rather than a taxon (Rees *et al.,* 2005) since the number of alive organisms in tubes are difficult to quantify. These organisms were included in count since they are visible on the seafloor and therefore considered as epibenthos. Brown algae and some red algae were not counted, but were instead measured with the percentage cover on the images, which is typical for algae (e.g. Kortsch *et al.,* 2012). In addition, bivalve shells were seen at some stations, but the proportion of dead or alive animals were unknown and these bivalves were therefore marked as “present” in the images. Bivalve shells were also difficult to separate from the sediment because of the quality on the images. Feeding strategies of the organisms were determined by scientific literature and are listed up in Table 3.

3.2.3 Environmental parameters

Environmental parameters were used to better describe the epibenthic communities in the scarcely studied the Kitikmeot Sea in CAA. Several environmental parameters (bottom temperature, bottom salinity, bottom oxygen, turbidity and sediment type) were recorded in vicinity of where images were taken. Salinity, temperature, oxygen and turbidity values closest to the seafloor were extracted from CTD casts using a Seabird SBE19 that was done in each area. Sediment grain size in the images was given a description of "hard bottom", "soft bottom" or "mixed sediment" and was used as an indicator and surrogate of long-term integrated current velocities. These categories were chosen based by what the images were dominated of. "Mixed sediment" is an intermediate category that was suited for the stations that had drastic changes in sediment grain size along a station transect. This implied for the transitional sites.

Size fractions of sediment were used to describe the seafloor features on the stations. The terms that were used for descriptions of seafloor features at the stations were boulder, cobble, pebble and sand. More categories within sediment size exists, but since sediment were determined visually from the images with support from distance between laser points, only these four categories were taken into account (for details see Wentworth 1922) due to limited visibility on image. The size fractions are listed up in Table 4.

Table 3: Epibenthic taxa that were recorded in imagery analyses from photos taken in the Kitikmeot Sea August 2016 from R/V Martin Bergmann. Physical specimens of epibenthic invertebrates was also collected by dredge to increase the confidence of identification on the images "likely identification". Feeding types of the taxa present on the images are labeled as: **pred** = predator and scavengers, **SDF** = Surface deposit feeder, **Sus** = Suspension feeder, **PP** = primary producer, **Gr. =** grazer and **n.d** = not defined. Taxa that were present at different stations are marked as "X".

Phylum	Taxon	Likely identification	Feeding type	AP1 (Algak Passage)	AP2 (Algak Passage)	TG (Turnagain Point)	UN4 (Finlayson Island)	TP (Tinney Gate)	UN1 (Finlayson Island)	UN2 (Finlayson Island)
Annelida	Polychaeta tube	-	**Sus** (Fauchald and Jumars 1979; Gaston, 1987)	X	X					
Annelida	Muddy polychaeta	-	**Sus** (Fauchald and Jumars 1979)		X					
Arthropoda	Decapoda (crab)	*Hyas* spp.	**Pred** (Hickman *et al* ., 2014)	X		X		X		
Arthropoda	Pycnogonida	-	**Pred** (Bell *et al* ., 2016; Taylor *et al* ., 2016)	X	X				X	
Chordata	Zoarcidae	-	**Pred** (Keats *et al.,* 1987)						X	
Cnidaria	Ceriantharia	-	**Sus** (Taylor *et al* ., 2016)	X	X	X	X			X
Cnidaria	Anthozoa	-	**Sus** (Taylor et al., 2016)	X	X	X	X	X	X	X
Cnidaria	*Gersemia* -like	*Gersemia* spp.	**Sus** (Bell et al., 2016; Taylor et al., 2016)						X	
Echinodermata	Ophiuroidea	*Ophiocten sericeum*	**SDF** (Bell *et al.* , 2016)	X	X	X	X	X		
Echinodermata	Asteroidea	-	**Pred** (Hickman *et al* ., 2014)	X	X	X	X	X	X	X
Echinodermata	*Urasterias lincki*	-	**Pred** (Divine *et al.,* 2015)	X		X				
Echinodermata	Pteraster spp. /*hymenaster* -like	-	**Pred** (Howell *et al.,* 2003)		X					
Echinodermata	Holothuriodea (red)	*Psolus* spp.	**Sus** (Bell *et al* ., 2016)			X	X	X	X	X
Echinodermata	Holothuroidea (purple)	*Cucumaria frondosa*	**Sus** (Mayer *et al* ., 1997)					X	X	X
Echinodermata	Holothuroidea sp.3	-	**Sus** (Bell *et al* ., 2016)						X	
Echinodermata	Echinoidea	*Strongylocentrotus pallidus*	**Grazer** (Hickman *et al* ., 2014)			X	X	X	X	
Echinodermata	Crinoidea	-	**Sus** (Bell *et al.,* 2016; Taylor et al., 2016)			X	X	X		X
Echinodermata	*Crossaster* spp.	*Crossaster papposus*	**Pred** (MacDonald *et al.,* 2010; Bell *et al* ., 2016)				X	X	X	X
Mollusca	Gastropoda	-	**n.d**	X	X			X	X	
Mollusca	*Hiatella* spp.	-	**Sus** (MacDonald *et al.,* 2010b)						X	
Mollusca	Polyplacophora	-	**Grazer** (Hickman *et al* ., 2014)						X	
Mollusca	Patellogastropoda	*Lepeta caeca*	**Grazer** (Branch 1981)		X		X	X	X	
Ochrophyta	Macroalgae percent	*Alaria esculenta* , *Laminaria* spp.	**PP**						X	
Rhodophyta	Algal dot	-	**PP**					X	X	
Rhodophyta	Red algae percent	-	**PP**				X	X	X	X
Rhodophyta	Coralline red algae	-	**PP**				X		X	X
Unknown	Anthozoa morphotype	-	**Sus** (Hickman *et al* ., 2014)	X						
Unknown	Bryozoa/hydrozoa/brown algae debris	-	**n.d**	X	X	X		X		
Unknown	*Hirudinea* -like	-	**n.d**						X	
Unknown	Ascidian/Anthozoa morphotype 1	-	**Sus** (Hickman *et al* ., 2014)				X		X	
Unknown	Anthozoa morphotype 2	-	**Sus** (Hickman *et al* ., 2014)	X		X	X			
Unknown	Soft coral white or sponge	-	**Sus** (Hickman *et al* ., 2014)				X		X	X
Unknown	Bryozoa/hydrozoa	-	**Sus** (Hickman *et al* ., 2014)		X				X	X
Unknown	White cotton-like cloud	-	**n.d**			X			X	

Table 4: Overview of size fraction used to describe the sediment found on the seafloor when analyszing images from the Kitikmeot Sea in Nunavut region, Canadian Arctic Archipelago. Sediment grain size values are from Wentworth (1922).

Sediment fraction	Size (mm)
Boulder	> 256
Cobble	64 – 256
Pebble	4 – 64
Sand	< 1

3.2.4 ***Data analyses***

The same software programs that were used to produce results from Northeast Greenland (see section 3.1.4 *Data analyses* for details) were also used for the Kitikmeot Sea study. Mean abundance per m^2 from each station were square-root transformed to even out the influence of the dominant species (Field *et al.,* 1982; Clarke and Warwick 2001; Johnson and Barmuta 2015). In this case, percentage cover of algae and count of taxa was collected during image analysis. These mixed values were included in the same data set for this part of my Master's thesis and same procedure has also been done in other studies as well (e.g. Beuchel *et al*., 2006; Kortsch *et al*., 2012). The drawback of using percentage cover and count is that they are not adjusted to the same standardization scale, but the Gower similarity coefficient (S15) (Gower 1971) solves issue this and align mixed scale data to same scale (Greenacre and Primicerio 2013, M. Greenacre, Universitat Pompeu Fabra, Barcelona, pers. comm.). Gower similarity coefficient was used to compute the similarities between the stations. Bray-Curtis was another option to choose because the range of the data were not extreme and not that different and could also been taken into account when considering correct similarity matrix (M. Greenarcre, Universitat Pompeu Fabra, Barcelona, pers. comm.). Again, HCA were used to identify similar taxa assemblages in dendrogram and nMDS were used to increase the confidence of ordinations. ANOSIM test were used to test if there was a statistically significant difference between the flow regimes in the study region.

4 Results

4.1 Northeast Greenland (NEG)

4.1.1 ***Epibenthic community structure in NEG***

4.1.1.1 Distribution of taxa richness for Campelen and Agassiz trawls

During both TUNU expeditions combined, a total of 276 putative epibenthic species were identified to the lowest possible taxonomic level from 33 Campelen and Agassiz hauls at 18 locations. The three phyla that contributed most to taxonomic richness in the study area were Arthropoda (27%), Porifera (17%) and Mollusca (15%) (Figure 4). The two locations with the highest taxa richness were interestingly at bank locations, Belgica Bank (1365-TUNUVII and 1368-TUNUVII) (88 taxa) and a bank along the 76° N latitudinal gradient (1346-TUNUVII and 1349-TUNUVII) (58 taxa), respectively (Figure 5). In contrast, the lowest taxa richness (8 taxa) was found at a deep location at the slope where sampling with only the Campelen trawl was conducted. The location with the second lowest taxa richness of 17 was also located at the slope, but both sampling gears were applied here. This was also the deepest location in the study area (994 – 1011 m) and had the lowest taxa richness of all locations that included both gears with a catch of eight taxa for the Campelen and nine taxa for the Agassiz trawl (Station 1357-TUNUVI and 1355-TUNUVI), where no taxa overlapped. At the shelf break locations (see Table 1 for identifying stations) the phylum Porifera had high taxa richness in the southern part of the study region (Figure 5). In Bessel Fjord, the number of taxa were relatively similar throughout the fjord. However, only one taxon from phylum Porifera was found at the inner fjord location which made it different from the other Bessel Fjord locations in terms of taxonomic composition.

In general, the number of taxa caught varied between the different gear types that were used. Taxa richness in Agassiz trawl hauls was higher compared to the Campelen trawl at 10 of 15 stations, while Campelen was higher than Agassiz hauls at five stations (Figure 6). Though station numbers are low in the study area, there appeared to be a habitat-specific shifting pattern in which gear type that caught more taxa from inner-fjord locations towards the shelf break and slope (Figure 6). Agassiz trawls conducted inside the fjord caught more taxa compared to the Campelen trawls. The shelf and shelf break stations had a less clear pattern though Campelen tended to catch more taxa on the shelf and Agassiz on the outer shelf. Towards the slope stations the Agassiz trawl again caught the highest taxa richness. Taxa accumulation curves for both gear types show that Agassiz trawl collected more taxa than Campelen. Additionally, it also suggests that sampling effort has not captured all epibenthic taxa present in the region (Figure 7).

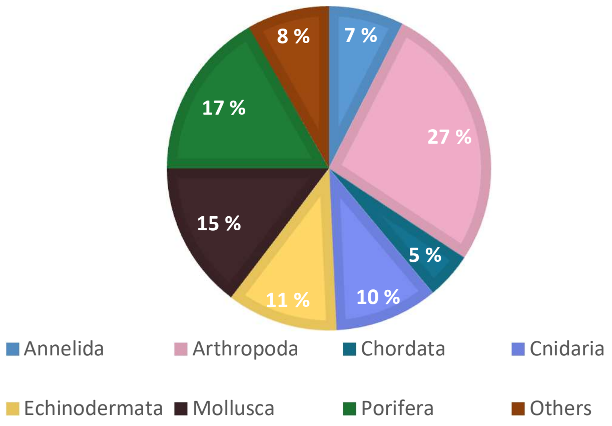


Figure 4: The total taxonomic composition of epibenthic invertebrates that was collected during TUNU-VI (2015) and TUNU-VII (2017) expeditions in Northeast Greenland (NEG) waters collected by Campelen 1800 trawl and Agassiz trawl.

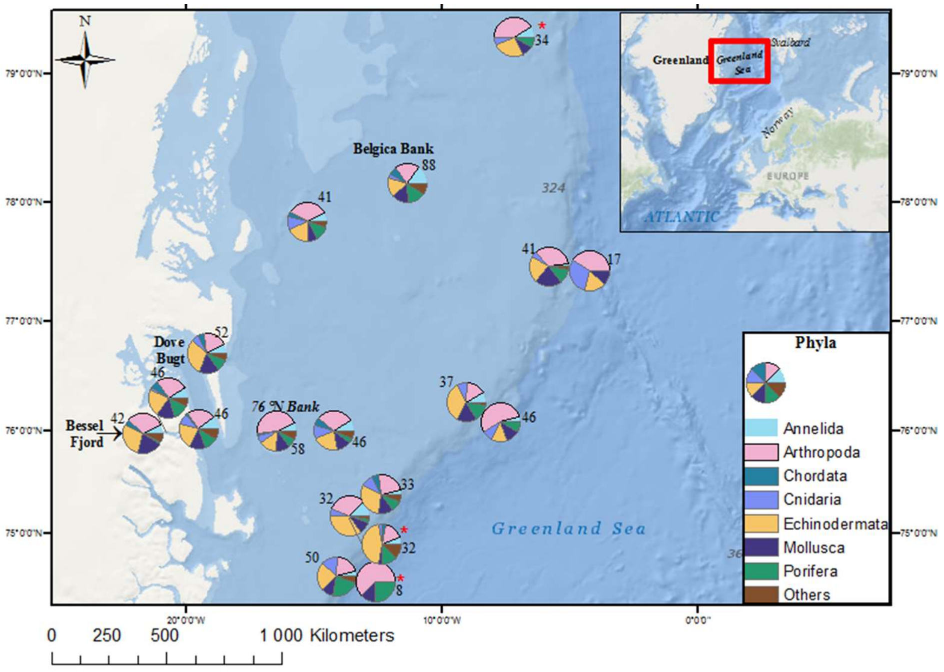


Figure 5: The pie charts in the map represent taxonomic composition of epibenthic invertebrates at eighteen locations where Campelen 1800 shrimp trawl and Agassiz trawl were deployed (i.e. taxonomical catches in Campelen and Agassiz were combined) during TUNU-VI (2015) and TUNU-VII (2017) expeditions to Northeast Greenland. The numbers indicate the total number of taxa that was found at each location for both sampling gear, except stations with (*), which means that only Campelen trawl hauls were performed at this location.

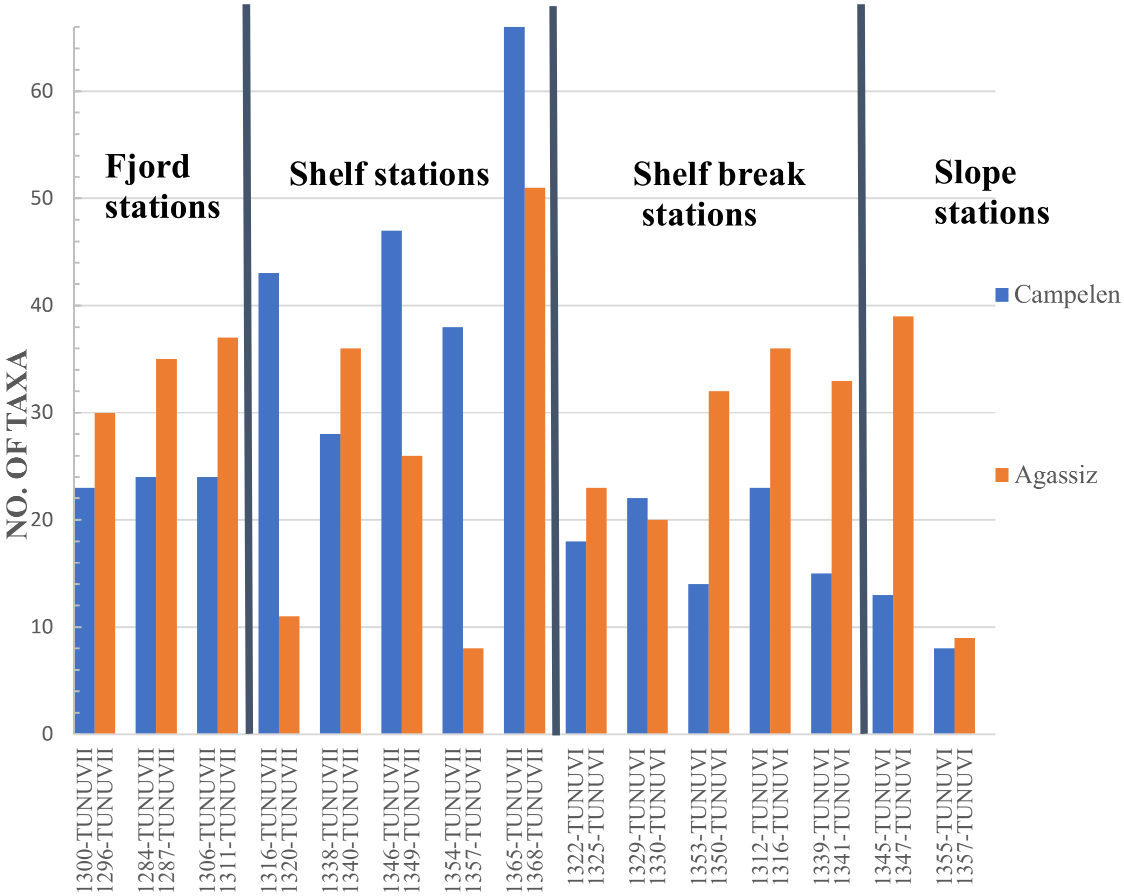


Figure 6: Number of taxa caught by Campelen 1800 shrimp trawl (blue) and Agassiz trawl (orange) during TUNU-VI (2015) and TUNU-VII (2017) expeditions to Northeast Greenland. Bar charts of Campelen and Agassiz trawls are closely put together for better visualization that they were taken at same location (not showing 1307-TUNUVI, 1321-TUNUVI and 1375-TUNUVII since not both gears were deployed at these locations).

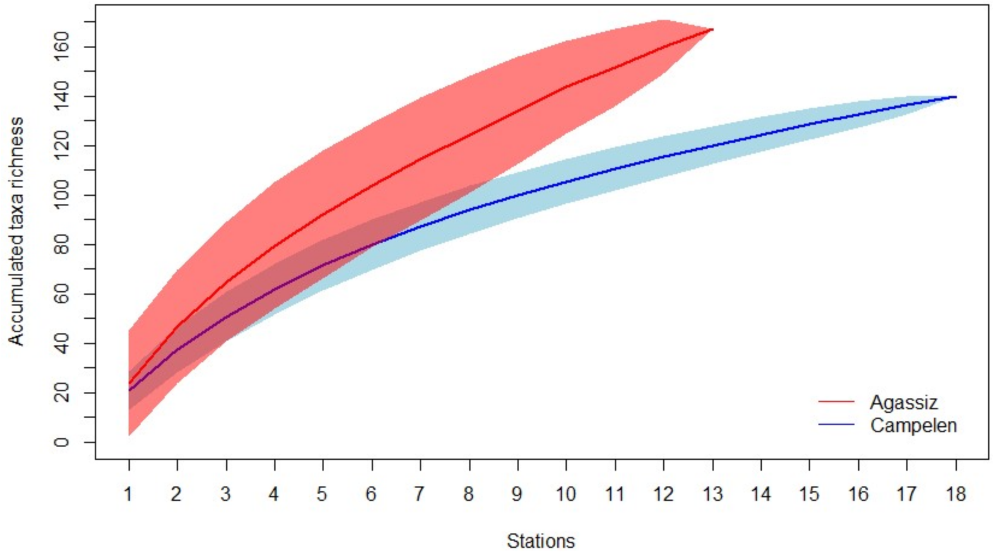


Figure 7: Taxa accumulation curve for the two gear types Campelen 1800 shrimp trawl and Agassiz trawl used during the two TUNU cruises to NEG in 2015 and 2017. Eighteen Campelen trawl stations and fifteen Agassiz trawl stations were collected and are shown here. Shaded light red and light blue area on the graph represent the confidence intervals for random samples.

4.1.1.2 Most frequent taxa found in NEG

In general, larger taxa and decapods were caught in the Campelen trawl whereas smaller taxa were caught in Agassiz trawl. Many of the taxa listed in Table 5 contributed to station similarity and dissimilarities, which will be mentioned in the section below. Some taxa were more frequently caught in the study area compared to others. Table 5 presents the top ten taxa that were caught most frequently for Campelen and Agassiz trawl. The polar shrimp *Lebbeus polaris* were present at all eighteen Campelen stations, whereas the brittle star *Ophiacantha bidentata* were present in twelve Agassiz trawls out of thirteen.

Table 5: Top ten benthic invertebrate taxa that were most frequent (frequency of occurrence = FO) across the study area during TUNU-VI (2015) and TUNU-VII (2017) expeditions caught in Campelen 1800 Shrimp trawl (18 stations) and Agassiz trawl hauls (15 stations).

	Taxa	**Phylum**	**Class**	**FO (Campelen)**	**Percentage (%) FO across study area 18 stations = 100 %**
1	***Lebbeus polaris***	Arthropoda	Decapoda	18	100.0
2	***Ophiopleura borealis***	Echinodermata	Ophiuroidea	13	72.2
3	***Sclerocrangon ferox***	Arthropoda	Decapoda	11	61.1
4	***Anonyx* spp.**	Arthropoda	Amphipoda	10	55.6
5	***Strongylocentrotus pallidus***	Echinodermata	Echinoidea	10	55.6
6	***Colus* spp.**	Mollusca	Gastropoda	10	55.6
7	***Sabinea septemcarinata***	Arthropoda	Decapoda	9	50.0
8	***Umbellula encrinus***	Cnidaria	Anthozoa	9	50.0
9	***Pontaster tenuispinus***	Echinodermata	Asteroidea	9	50.0
10	***Gorgonocephalus* spp.**	Echinodermata	Ophiuroidea	9	50.0
	Taxa	**Phylum**	**Class**	**FO (Agassiz)**	**Percentage (%) FO across study area 13 stations = 100 %**
1	***Ophiacantha bidentata***	Echinodermata	Ophiuroidea	12	92.3
2	***Ophiopleura borealis***	Echinodermata	Ophiuroidea	11	84.6
3	***Ophiocten sericeum***	Echinodermata	Ophiuroidea	11	84.6
4	***Sclerocrangon ferox***	Arthropoda	Decapoda	8	61.5
5	***Pontaster tenuispinus***	Echinodermata	Asteroidea	8	61.5
6	***Lebbeus polaris***	Arthropoda	Decapoda	7	53.8
7	***Colus* spp.**	Mollusca	Gastropoda	7	53.8
8	***Boreonymphon* spp. No eyes**	Arthropoda	Pycnogonida	7	53.8
9	***Nothria conchylega***	Annelida	Polychaeta	7	53.8
10	***Icasterias panopla***	Echinodermata	Asteroidea	7	53.8

4.1.1.3 Abundance and biomass

The estimated swept area covered by the semi-quantitative Campelen trawl varied from 9,641 m^2 to 20,817 m^2 for both years. Epibenthic abundance across the NEG study region ranged from 4.1 ind. per 1000 m^2 at shelf break station 1322-TUNUVI to 854.1 ind. per 1000 m^2 at shelf station 1346-TUNUVII across the 18 Campelen stations (Table 1, Figure 8A). The two Campelen stations with the highest estimated abundance were interestingly found at both bank stations located at the shelf. Station 1346-TUNUVII (76º N Bank) had 854.1 ind. per 1000 m^2 and station 1365-TUNUVII (Belgica Bank) had 64.0 ind. per 1000 m^2, respectively. At both stations abundance was dominated by a single species each: The bivalve (Mollusca) *Similipecten greenlandicus* was by far the taxon that contributed most to abundance at station 1346-TUNUVII, whereas the ophiuroid (Echinodermata) *Ophiopleura borealis* dominated by abundance at station 1365-TUNUVII (Figure 8B).

The two innermost stations in Bessel Fjord were dominated in abundance by echinoderms, specifically *Ophiopleura borealis* (inner fjord), whereas the station located at the mouth of the fjord was dominated by asteroids *Ctenodiscus crispatus* in abundance. The dominance of which taxa that had the highest abundance varied across the five shelf stations. In comparison to the two bank stations at the shelf, the three remaining shelf stations did not have that high abundance. One of the shelf stations 1316-TUNUVII located in Dove Bugt, had high abundances of crinoids (*Heliometra glacialis* and *Poliometra polixa*, respectively) and were the species that contributed to the high abundance in phylum Echinodermata (Figure 8B). Mainly Arthropoda dominated in abundance at shelf station 1354-TUNUVII where the amphipod *Eusirus* spp. was the contributor, whereas shelf station 1338-TUNUVI was also dominated by Arthropoda by abundance, but rather the polar shrimp *Lebbeus polaris*. The abundances at the shelf break and slope stations were very low and varied only from 4.1 ind. per 1000 m^2 at shelf break station 1322-TUNUVI to 37.3 ind. per 1000 m^2 at shelf break station 1312-TUNUVI. The stations along the shelf break and slope were dominated in abundance by Arthropoda and Echinodermata (Figure 8B). Again, single species contributed to abundance, specifically from south to north *Lebbeus polaris, Strongylocentrotus pallidus* (pale sea urchin), *Pasiphaea tarda* (Crimson glass shrimp), *Sclerocrangon ferox* (warrior shrimp), *Gonatus* spp. (squid) and *Sabinea septemcarinata* (sevenline shrimp), respectively.

Biomass estimates from TUNU-VII ranged from 65.0 g ww per 1000 m^2 at fjord station 1300-TUNUVII to 527.7 g ww per 1000 m^2 at shelf station 1316-TUNUVII (Figure 8C). The highest estimated biomass from the Campelen trawl during 2017 was found at station 1316-TUNUVII in Dove Bugt, where the basket star *Gorgoncephalus* spp. was the main contributor to high biomass (Figure 8D). The station with the second highest biomass was shelf station 1346-TUNUVII located at the bank on the 76º N latitude with 374.2 g ww per 1000 m^2. Here, mainly the bivalve *Similipecten greenlandicus* contributed to the biomass at this station.

Stations from inside of Bessel Fjord towards the mouth were dominated by holothuroid *Molpadia borealis* (two innermost stations) and *Forcepia*-like sponges, respectively. Further out on the shelf at station 1338-TUNUVII, high estimated biomass were mainly because of catches of *Pandalus borealis* (deep water shrimp) and were only caught at this station during sampling on the TUNU-VII expedition in 2017. Station 1375-TUNUVII was the only station at the shelf break where estimates of biomass were calculated, since this was the only shelf break station that was visited during TUNU-VII expedition. Here at this station, *Sclerocrangon ferox* was the main contributor to the biomass. Additionally, detailed information about relative taxonomic composition in count and weight by phyla between trawl gears can be seen in Appendix Figure 1 and Appendix Figure 2.

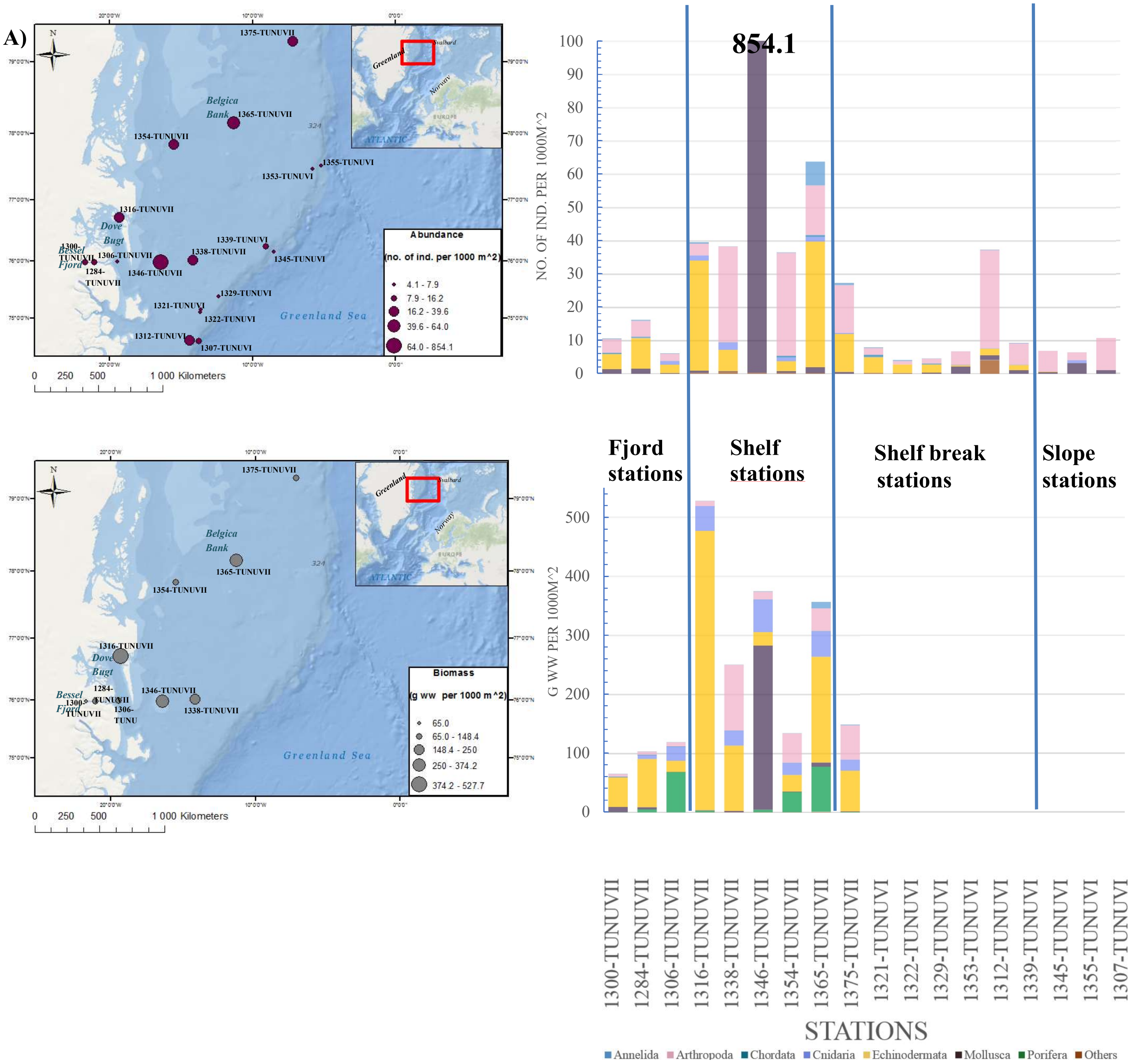


Figure 8: A) Distribution of epifaunal abundance (no. of ind. per 1000 m^2) from Campelen 1800 shrimp trawl from the TUNU expeditions to Northeast Greenland in 2015 and 2017. Scaled circles of abundance and biomass were adjusted to Jenks' natural breaks. **B)** estimated abundance for both years, **C)** Distribution of biomass (g ww per 1000 m^2) for epifaunal catches for 2017 only and **D)** Estimated biomass caught during TUNU-VII (2017).

4.1.1.4 Spatial pattern in epibenthic communities

First, I had to decide if Campelen and Agassiz trawl could be combined for the multivariate analysis. Factor gear was tested and showed a statically significant difference between the gears Campelen trawl and Agassiz trawl using relative abundance data, where Global R suggests little separation (ANOSIM, global R = 0.18, p = 0.007). Therefore, further analyses were only conducted for abundance-based estimates for Campelen trawl to reduce possible biases, but ordination results of both gears can be seen in Appendix Figure 3A, Appendix Figure 3B. This resulted in 18 remaining Campelen stations that could be used for the multivariate analyses.

Hierarchical cluster analysis (HCA) with group average linkage revealed that the different factors habitat type had a distinct separation in the dendrogram for abundance-based data with fourth-root transformation (Figure 9A). Six clusters in the dendrogram were statistically significant different (SIMPROF analysis with $\alpha = 0.05$). The ordination of the stations in the nMDS showed an even more distinct pattern of habitat separation (Figure 9B). Most of the clusters contained stations with same habitat type categories (Figure 9A, Figure 9C).

There was a statistically significant difference between the communities when habitat type were used as a factor in one-way ANOSIM, where also Global R suggested a large separation between the habitat types (Global R=0.78, p = 0.001) Table 6. The pairwise test showed that the communities were statistically significant different, except the communities with habitat type fjord and slope different (ANOSIM, R = 1, p = 0.1). The largest differences between the communities were found between shelf break and fjord (R=0.845, p=0.008) and shelf break and slope habitats (R=0.754, p=0.008). More details can be seen in Appendix Table 3.

Table 6: The results from the one-way ANOSIM test, where differences between the trawl gears (Campelen 1800 Shrimp trawl and Agassiz trawl) and habitat types (Fjord, shelf, shelf break and slope) were tested for Campelen 1800 Shrimp trawl only.

Factors tested	**Data type**	**Global R**	**p-value**
Trawling gears	Relative abundance	0.18	0.007
Habitat type for Campelen trawl	Abundance	0.78	0.001

The taxa that contributed most to similarity within the community groups and dissimilarities between the community groups based on the SIMPER analysis are shown in Table 7 and Table 8. Average similarity percentages within the community groups varied from 37.0 to 48.7 % and was highest for habitat type slope and lowest for habitat type shelf break. *Ophiopleura borealis* was the species that contributed to most average similarity within the fjord stations, whereas *Lebbeus polaris* to the shelf stations, *Sclerocrangon ferox* to the shelf break stations and *Gonatus* spp. to slope stations. Other species and taxa that contributed to approximately 50% to the similarity within the community groups can be seen in Figure 7. Much more taxa contributed to the average dissimilarity, than average similarity. Between 11 and 29 species contributed approximately 50% to the average dissimilarity between the communities, where the average dissimilarity between the community groups varied from 69.2 to 91.1 % (Table 8). The three taxa in each community group that contributed most to the dissimilarities are shown in Table 8 and are largely combinations of the taxa in Table 7.

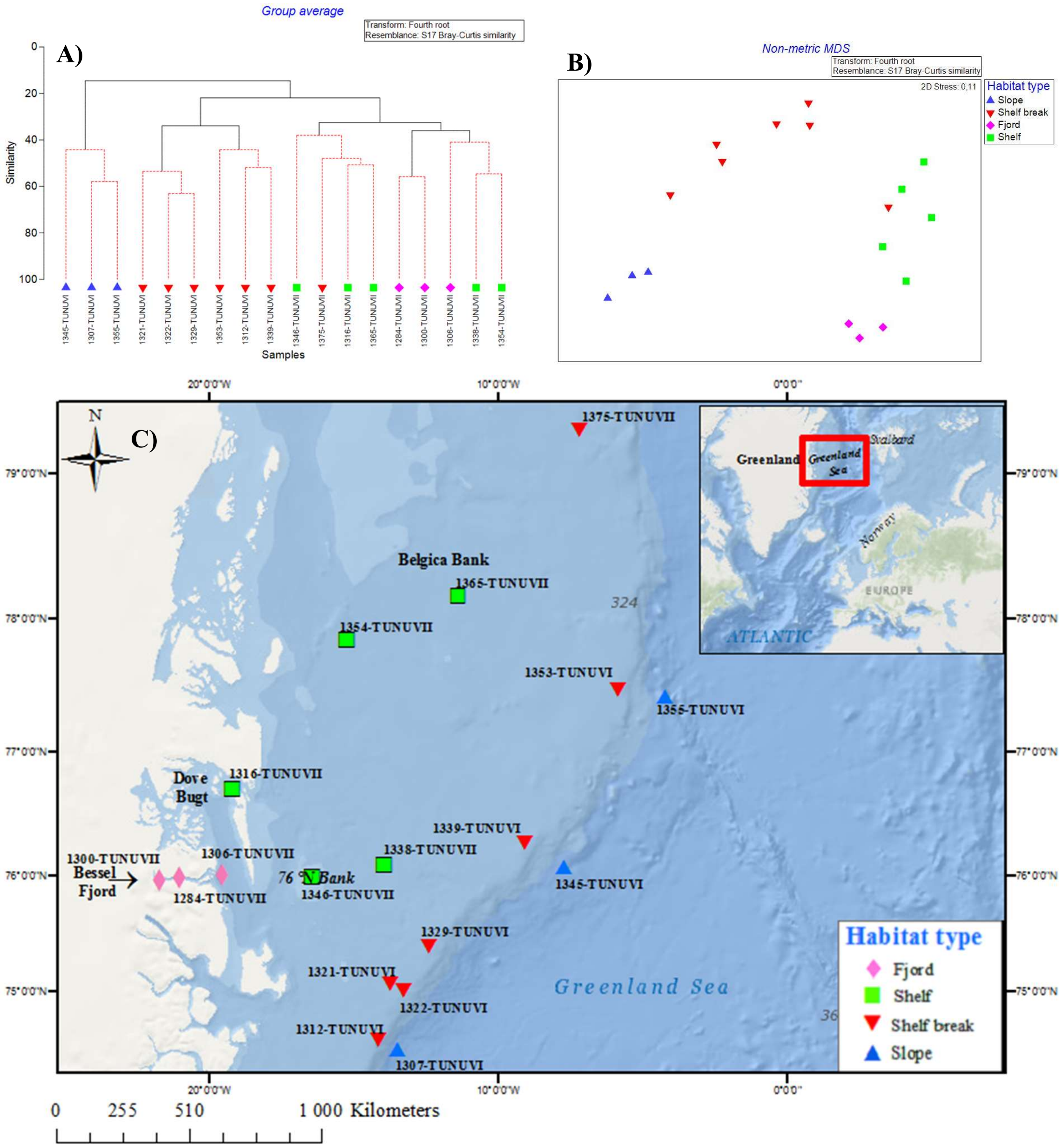
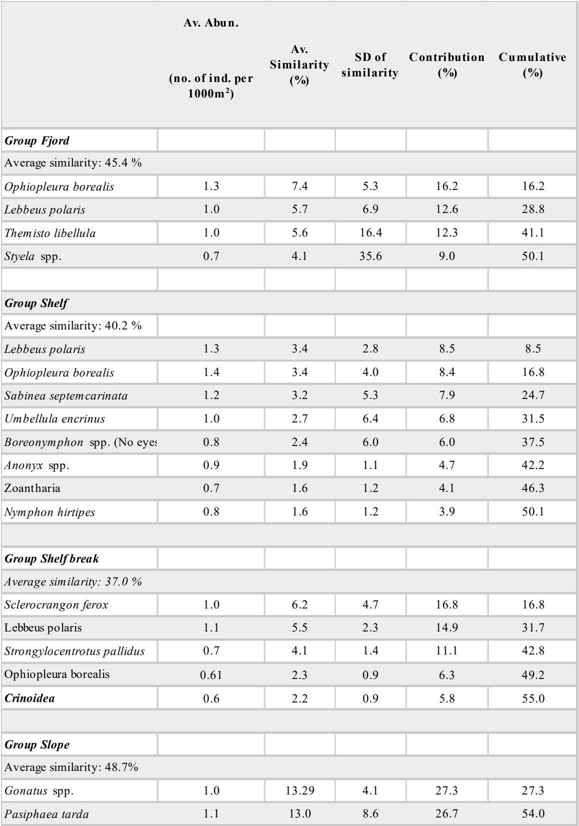


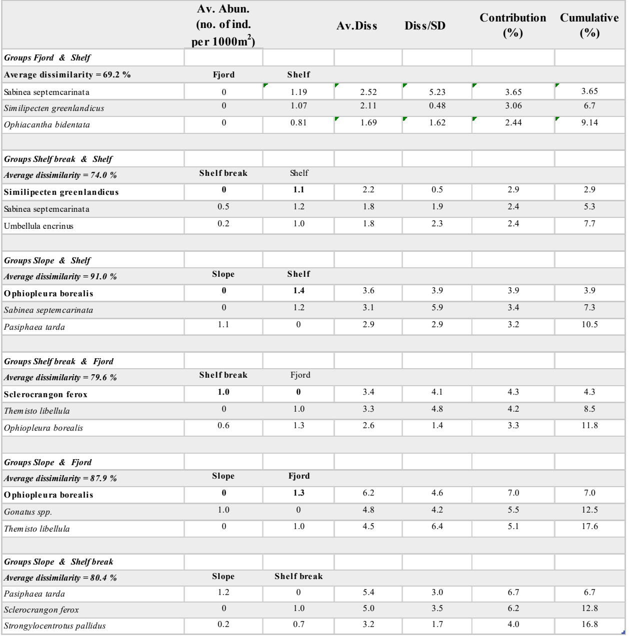
Figure 9: Station similarities where the stations are grouped by habitat type. **A)** Station clusters that were obtained from the hierarchical cluster analysis with fourth-root transformed abundance-based data, **B)** nMDS plot of the abundance-based data and **C)** The distribution of habitat type clusters of Campelen 1800 Shrimp trawl stations collected during TUNU-VI and TUNU-VII. Habitat types were used in the multivariate statistics.

Table 7: Epifaunal taxa caught in Campelen 1800 Shrimp trawl that contributes approximately 50 % of the similarity within the four community groups that were used to detect a pattern in nMDS and hierarchical clustering**.**



	Av. Abun. (no. of ind. per $1000m^2$)	**Av. Similarity (%)**	**SD of similarity**	**Contribution (%)**	**Cumulative (%)**
Group Fjord					
Average similarity: 45.4 %					
Ophiopleura borealis	1.3	7.4	5.3	16.2	16.2
Lebbeus polaris	1.0	5.7	6.9	12.6	28.8
Themisto libellula	1.0	5.6	16.4	12.3	41.1
Styela spp.	0.7	4.1	35.6	9.0	50.1
Group Shelf					
Average similarity: 40.2 %					
Lebbeus polaris	1.3	3.4	2.8	8.5	8.5
Ophiopleura borealis	1.4	3.4	4.0	8.4	16.8
Sabinea septemcarinata	1.2	3.2	5.3	7.9	24.7
Umbellula encrinus	1.0	2.7	6.4	6.8	31.5
Boreonymphon spp. (No eye	0.8	2.4	6.0	6.0	37.5
Anonyx spp.	0.9	1.9	1.1	4.7	42.2
Zoantharia	0.7	1.6	1.2	4.1	46.3
Nymphon hirtipes	0.8	1.6	1.2	3.9	50.1
Group Shelf break					
Average similarity: 37.0 %					
Sclerocrangon ferox	1.0	6.2	4.7	16.8	16.8
Lebbeus polaris	1.1	5.5	2.3	14.9	31.7
Strongylocentrotus pallidus	0.7	4.1	1.4	11.1	42.8
Ophiopleura borealis	0.61	2.3	0.9	6.3	49.2
Crinoidea	0.6	2.2	0.9	5.8	55.0
Group Slope					
Average similarity: 48.7%					
Gonatus spp.	1.0	13.29	4.1	27.3	27.3
Pasiphaea tarda	1.1	13.0	8.6	26.7	54.0

Table 8: The top three epifaunal taxa caught in Campelen 1800 Shrimp trawl that contributes to dissimilarity between the community groups that were used to detect a pattern in nMDS and hierarchical clustering.



	Av. Abun. (no. of ind. per $1000m^2$)		**Av.Diss**	**Diss/SD**	**Contribution (%)**	**Cumulative (%)**
Groups Fjord & Shelf						
Average dissimilarity = 69.2 %	**Fjord**	**Shelf**				
Sabinea septemcarinata	0	1.19	2.52	5.23	3.65	3.65
Similipecten greenlandicus	0	1.07	2.11	0.48	3.06	6.7
Ophiacantha bidentata	0	0.81	1.69	1.62	2.44	9.14
Groups Shelf break & Shelf						
Average dissimilarity = 74.0 %	**Shelf break**	Shelf				
Similipecten greenlandicus	**0**	**1.1**	2.2	0.5	2.9	2.9
Sabinea septemcarinata	0.5	1.2	1.8	1.9	2.4	5.3
Umbellula encrinus	0.2	1.0	1.8	2.3	2.4	7.7
Groups Slope & Shelf						
Average dissimilarity = 91.0 %	**Slope**	**Shelf**				
Ophiopleura borealis	**0**	**1.4**	3.6	3.9	3.9	3.9
Sabinea septemcarinata	0	1.2	3.1	5.9	3.4	7.3
Pasiphaea tarda	1.1	0	2.9	2.9	3.2	10.5
Groups Shelf break & Fjord						
Average dissimilarity = 79.6 %	**Shelf break**	Fjord				
Sclerocrangon ferox	**1.0**	**0**	3.4	4.1	4.3	4.3
Themisto libellula	0	1.0	3.3	4.8	4.2	8.5
Ophiopleura borealis	0.6	1.3	2.6	1.4	3.3	11.8
Groups Slope & Fjord						
Average dissimilarity = 87.9 %	**Slope**	**Fjord**				
Ophiopleura borealis	**0**	**1.3**	6.2	4.6	7.0	7.0
Gonatus spp.	1.0	0	4.8	4.2	5.5	12.5
Themisto libellula	0	1.0	4.5	6.4	5.1	17.6
Groups Slope & Shelf break						
Average dissimilarity = 80.4 %	**Slope**	**Shelf break**				
Pasiphaea tarda	1.2	0	5.4	3.0	6.7	6.7
Sclerocrangon ferox	0	1.0	5.0	3.5	6.2	12.8
Strongylocentrotus pallidus	0.2	0.7	3.2	1.7	4.0	16.8

4.1.2 Environmental variables that can explain epibenthic communities

Out of the six environmental variables considered in the combined 2015-2017 data set (latitude, depth, bottom salinity, bottom temperature, bottom oxygen and turbidity) (Table 9), where the combination of depth and bottom oxygen were the two variables that best correlated with the biological parameters (correlation coefficient 0.671) (Table 9). The single variable with the highest correlation coefficient was depth for both BIO-ENV analyses. When the three additional environmental variables (integrated chlorophyll a, percentage of sand and percentage of mud) were included for the latter cruise only, the combination of depth and bottom salinity were correlating best with the biological parameters (0.530). The correlation coefficient was in general lower for TUNU-VII when more environmental variables were included (Table 9).

Table 9: Biological-Environmental (BIO-ENV) results. This table has results from both TUNU expeditions in 2015 and 2017 when six environmental variables (depth, latitude, bottom temperature, bottom salinity, turbidity, bottom oxygen) were correlated with the biological variables. Additional BIO-ENV routine were performed for three additional variables collected during TUNU-VII (integrated chlorophyll a, percentage sand and percentage mud).

No. Of environmental variables	**ENV. variables with best combination to epibenthic community**	**Correlation coefficient**
Environmental variables from TUNU-VI (2015) and TUNU-VII (2017)		
1.	*Depth*	0.577
2.	*Depth, Bottom oxygen*	0.671
3.	*Depth, Bottom oxygen, Turbidity*	0.641
4.	*Depth, Bottom oxygen, Bottom salinity*	0.562
5.	*Depth, Bottom oxygen, Bottom temperature, Bottom salinity, Turbidity*	0.486
6.	*Latitude, Depth, Bottom oxygen, Bottom temperature, Bottom salinity, Turbidity*	0.428
Additional environmental variables from TUNU-VII (2017)		
1.	*Depth*	0.378
2.	*Depth, Bottom salinity*	0.530
3.	*Depth, Bottom salinity, Integrated chla*	0.529
4.		0.528
5.	*Depth, Bottom oxygen, Bottom salinity, Turbidity, Integrated chla*	0.486
6.	*Latitude, Depth, Bottom oxgen, Bottom salinity, Turbidity, Integrated chla*	0.459
7.	*Latitude, Depth, Bottom oxygen, Bottom salinity, Turbidity, Integrated chla*	0.439
8.	*Latitude, Depth, Bottom oxygen, Bottom temperature, Bottom salinity, Turbidity, Integrated chla, Percentage sand*	0.364
9.	*Latitude, Depth, Bottom oxygen, Bottom temperature, Bottom salinity, Turbidity, Integrated chla, Percentage sand, Percentage mud*	0.311

Principal Component Analysis was conducted to explore the spatial variability in the environmental parameters in the study area, where Principal Component 1 (PC1) and Principal component 2 (PC2) explained 74.3 % of the variability between the stations. The fjord stations were mostly spread along the PC1 axis that explained 54.9 % of the variation (Figure 10, Table 10). Here, turbidity, bottom oxygen and bottom temperature were the drivers to the variation between the fjord stations. The shelf stations were more closely clustered together compared to fjord stations and were explained by bottom temperature. One shelf station was more distinct compared to the other shelf stations and was more explained by turbidity and bottom oxygen rather than bottom temperature. The shelf break stations were clustering together where temperature accounted for the little variation between the stations. The slope stations were strongly grouped together by depth.

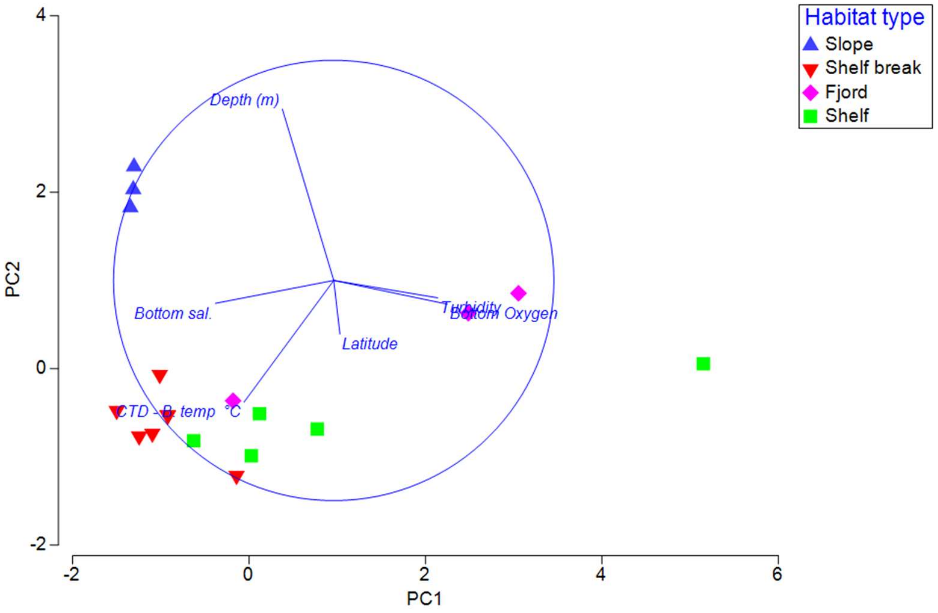


Figure 10: Ordination of Principal Component Analysis (PCA) of six environmental variables (depth, latitude, bottom salinity, bottom temperature, bottom oxygen and turbidity) that were collected during TUNU-VI (2015) and TUNU-VII (2017) cruises. The vectors depicted in the graph are representing the direction and the strength of the environmental variables at each station based on Campelen 1800 Shrimp trawls.

Table 10: Principal Component Analysis (PCA) of the normalized environmental variables, showing the two first principal components that explain >74 % of the variation in the environmental variables.

	PC1	**PC2**
Eigenvalues	3.3	1.16
% Variation	54.9	19.3
Cum. % Variation	54.9	74.3
Eigenvectors		
Latitude	0.028	-0.244
Depth (m)	-0.233	0.779
Bottom Oxygen	0.516	-0.108
Bottom temp. (°C)	-0.408	-0.553
Bottom sal.	-0.538	-0.104
Turbidity	0.472	-0.079

4.2 Kitkmeot Sea, Canadian Arctic Archipelago

4.2.1 Image analysis

Approximately 20 minutes were used per image at the locations with low current flow regime (AP1 and AP2) during the image analysis, whereas approximately 30 minutes was used per image at the remaining stations since there were more information in the latter ones. Calculated image area varied within the station along the transect (Table 2).

4.2.2 Station observations and conspicuous taxa

4.2.2.1 Low flow sites

Algak Passage

Both Algak Passage stations were located in Bathurst Inlet (Figure 3) with low current velocities compared to the other stations as reflected in the sediment and the drift speed of the vessel (Table 2).

AP1

Station Algak Passage (AP1) had a relatively homogenous substrate that was entirely composed of sand and finer grained sediment (Figure 11A), but consisted mostly of soft bottom. Few epifaunal taxa were present at this site, with Ophiuroidea as the most frequent taxon along the station transect. Some Anthozoa morphotypes and Polychaeta tubes were recorded, but were not nearly as abundant as the brittle stars. No obvious natural light source reached down to the seafloor at this station transect, where the start depth was 75 m**.** This was the second deepest station and had the second slowest drift speed of the vessel in the entire study region (Table 2), which could also be reflected in the sediment.

AP2

Coarser sediment such as pebble and cobble was present along the AP2 station transect, but was also composed of sand and/or smaller grain sizes (Figure 11B). However, the station were fairly dominated by fine sediment on the images and named as a soft bottom site. Similar to AP1, Ophiuroidea were also very highly abundant at this station. In contrast to AP1, Patellogastropoda could be observed and was seen when attached to the gravel. An unidentified taxon that was given the descriptive name "Muddy Polychaeta morphotype" was only observed at this low flow site. Polychaeta tubes and Anthozoa were also present here and no natural light was visible. This station represented the deepest station with a start depth of 93 m. The Drift speed of the boat was so low that it was nearly indiscernible.

4.2.2.2 Transitional sites

TG

Station Tinney Gate (TG) located further into Bathurst Inlet in a narrow passage between and island and the mainland, had varied seabed morphology with very heterogeneous sediment along the transect (Figure 11C) and were hence given the sediment type description intermediate/mixed sediment. The size of the sediment varied along the station transect with some images dominated by pebble, cobble and others by soft sediment seafloor. Part of the seafloor was covered by grey, carpet-like organic material. This layer made it difficult to see what was present on the seafloor underneath and also what kind of organisms were present in the images. It was impossible to verify what the carpet-like organic material was and, therefore, the percentage cover of this material was not measured at this station. In some images, a type of red alga with a distinct shape and color occurred and was measured by percentage cover. The taxa that were most present during the transect was Crinoidea and Holothuroidea. The station had a start depth of 25 m along the transect and weak natural light penetrated the water column to the seafloor. In addition, the drift speed of the boat was recorded to be the highest of all sites at this region (1.25 kn). Consequently, half of the photos from this station unfortunately had to be excluded due to blurry photos, leaving only 29 images available for image analysis. High particle density flowing in the water column was visible by the reflection by the artificial light.

UN4

Station UN4 were in vicinity of Finlayson Island, but taken during transition. Along the station transect UN4 sediment was very heterogeneous, but mostly cobbles and also boulders with encrusting coralline red algae were present (Figure 11D) and had the sediment type description intermediate/mixed sediment. In some of the images, the seafloor consisted of sand and finer sediment combined with pebble. In the middle towards the end of the station transect, the sediment was covered with red carpet-like organic material and made it challenging to see epibenthos. Station UN4 had a start depth of 47 m, where little natural light source could be seen on the images. On many of the images it was too difficult to see the seafloor and to distinguish the different taxa and also some of the images were too blurry. Therefore, only 25 images for this station were used for the image analysis. Crinoidea, Echinoidea, and other Echinodermata, such as Asteroidea were the most prominent taxa present in the beginning of the station transect. Additionally, taxa composition changed towards the end of transect, where Ophiuroidea were dominating.

4.2.2.3 High flow sites

TP

Seafloor at Turnagain Point (TP) located in Dease Strait, was mostly covered by pebble and cobble along transect (Figure 11E), but towards the end some images showed a seafloor that consisted of solid bedrock and was given the sediment type as hard bottom. Between the different grain sizes, some bivalve shells were present on the images. Natural light was detected in all of the images along the station transect, where the start depth was 30 m at this station. Crinoidea were present throughout the whole transect, where Holothuroidea occasionally were found together with the Crinoidea when seafloor consisted of pebble and cobble. When there was a change in sediment features from pebbles and cobbles to solid bedrock, one could then see a change in taxa composition and “red algal dots” became abundant.

Finlayson Island

UN1

The UN 1 station transect in the Finlayson Islands had a seafloor that mostly consisted of pebble and cobble and had a high cover of coralline red algae (Figure 11F) and was named hard bottom due to its sediment type**.** Some bivalve shells were present between the sediment. Shallow depth of 20 m and presence of natural light resulted in a large proportion of kelp that covered a big portion on the images. Current velocity was high at this station, which could be seen in the images since the kelps laid flat on the seafloor on the images. However, the drift speed of the vessel was recorded to be only 1 kn. A more diverse group of taxa was present at this station compared to the other stations, and many of these were attached to hard surfaces with limited motility, and where sessile and colonial (e.g. Polyplacophora, Patellogastropoda and Nephtheidae and Hydrozoa, respectively). It was possible to see that some of the nephtheid soft coral colonies had different colors, but were however, grouped into same taxon due to difficulties with consistent identification only based on the images (Figure 11F). A family of benthic fish (Zoarcidae) could be observed in some of the images.

UN2

Station UN2 transect, also located in vicinity of Finlayson Island had sediment grain size that mostly consisted of pebble and cobble (Figure 11G) and was twice as deep as the previous station UN1 with 42 m. The sediment type at this station was determined as hard bottom based since the sediment sizes mostly consisted by pebble and cobble. Here, very little and no natural light could be seen on the seafloor images. The drift speed of the vessel was recorded to be 0.5 kn. Coralline red algae could also be observed in some of the pictures where the artificial light reached the seafloor. Many of the images did not fill the requirements that were mentioned in the method part, leaving 28 images for the image analysis. On these images along the station transect, there were found mostly Crinoidea throught the whole transect together with Holothuroidea. Holothuroidea were most abundant in the middle of the station transect and declined towards the end. Cnidaria (mostly soft corals) could occasionally be seen along the station transect.

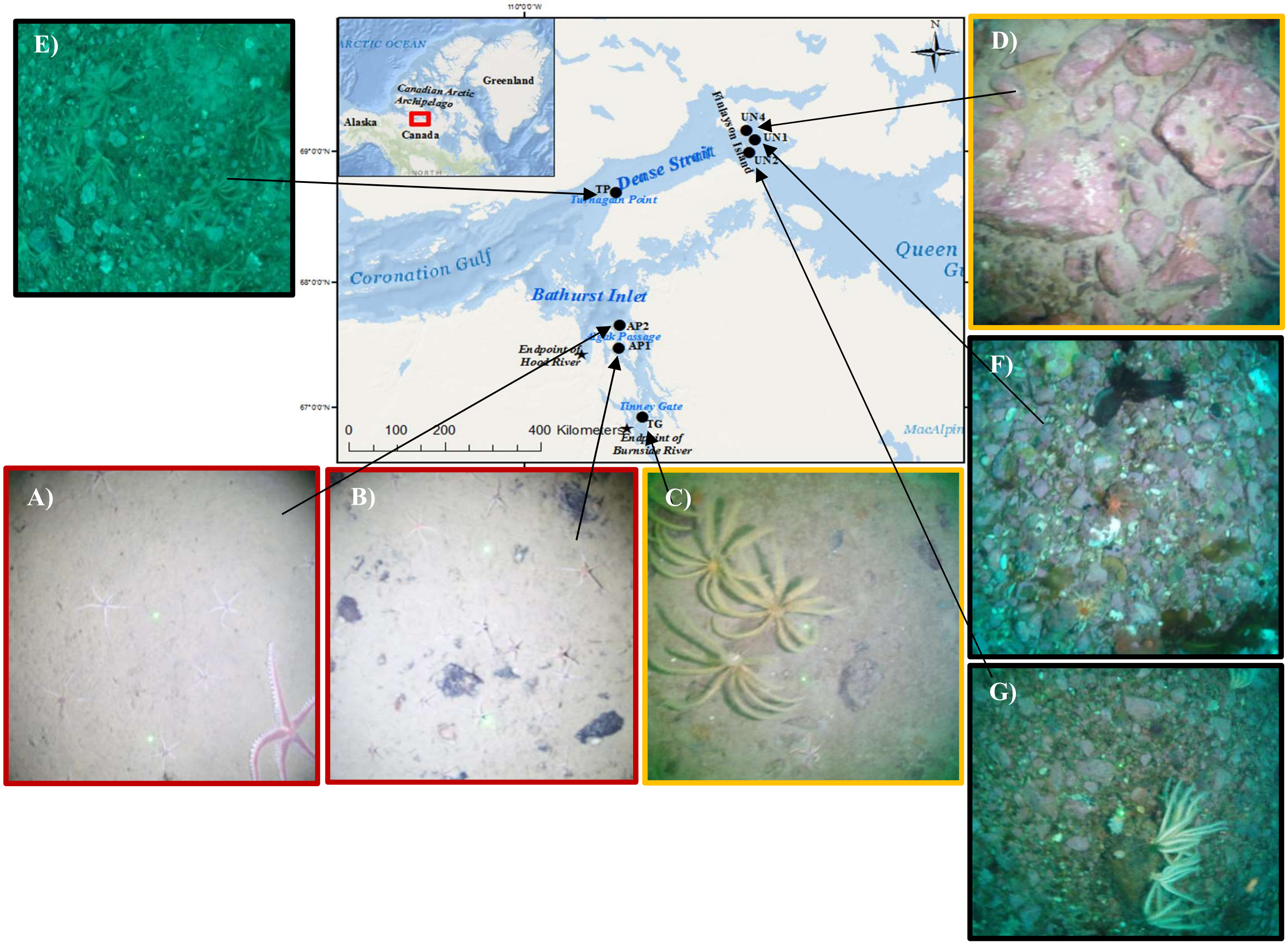


Figure 11: An overview of the stations that were visited for image taking of the seafloor in the Kitikmeot Sea in 2016 with example photos from each station. Images with red frame represent the stations collected at sites with low current velocity, yellow frame at transitional sites and black frame sites with high current velocity. **Low flow sites**: **A)** Algak Passage 1 (AP1) where a large *Urasterias lincki* can be seen with many ophiuroids on soft bottom, **B)** Algak Passage 2 (AP2) many ophiuroids together with some pattellids present on pebble and cobble. **Transitional sites**: **C)** Tinney Gate (TG) *Urasterias lincki* can be seen at the bottom of the image together with the dominating crinoids, **D)** Finlayson Island (UN4) echinoids present on boulder together with crinoids. **High flow sites**: **E)** Turnagain Point (TP) dominated by crinoids together with red algae (Rhodophyta), **F)** Finlayson Island (UN1) holothuroids were present on the images where brown algae (Ochrophyta) dominated with Cnidaria **G)** Finlayson Island (UN2), present on the images were mostly holothuroids, but here crinoids can be seen.

4.2.3 Taxa richness distribution

During image analysis, 33 putative epibenthic species were identified to the lowest possible taxonomic level. The most taxa rich phylum was Echinodermata (31 %), followed by Mollusca (12 %), Cnidaria (9 %), Macroalgae (9 %), Annelida (6 %), Arthropoda (6 %) and Chordata (3%) and Ochrophyta (3%) (Figure 12). Morphotypes and taxa where the phylum level could not be identified accounted for 24% of the total taxa recognized on the images. The highest taxa richness was found at station UN1 with 22 taxa (Figure 13). In contrast, the stations with the lowest taxa richness were AP2 and UN2 with 11 recognized taxa each on the images (Figure 13). Throughout the study area, the phylum Echinodermata was the most taxon rich group at all stations. Taxa that were present at different stations can be seen in Table 3.

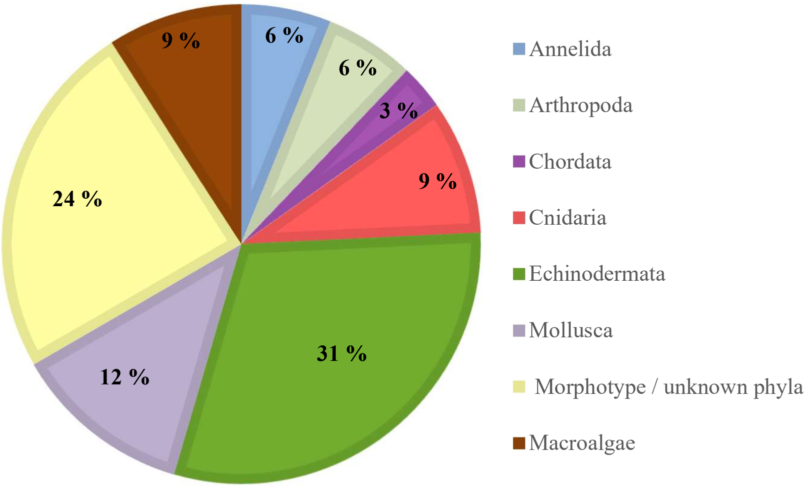


Figure 12: Total invertebrate taxonomic composition from the Kitikmeot Marine Science study in 2016 from the images that were analyzed from seven stations. Red algae (Rhodophyta) and brown algae (Ochrophyta) were combined as macroalgae.

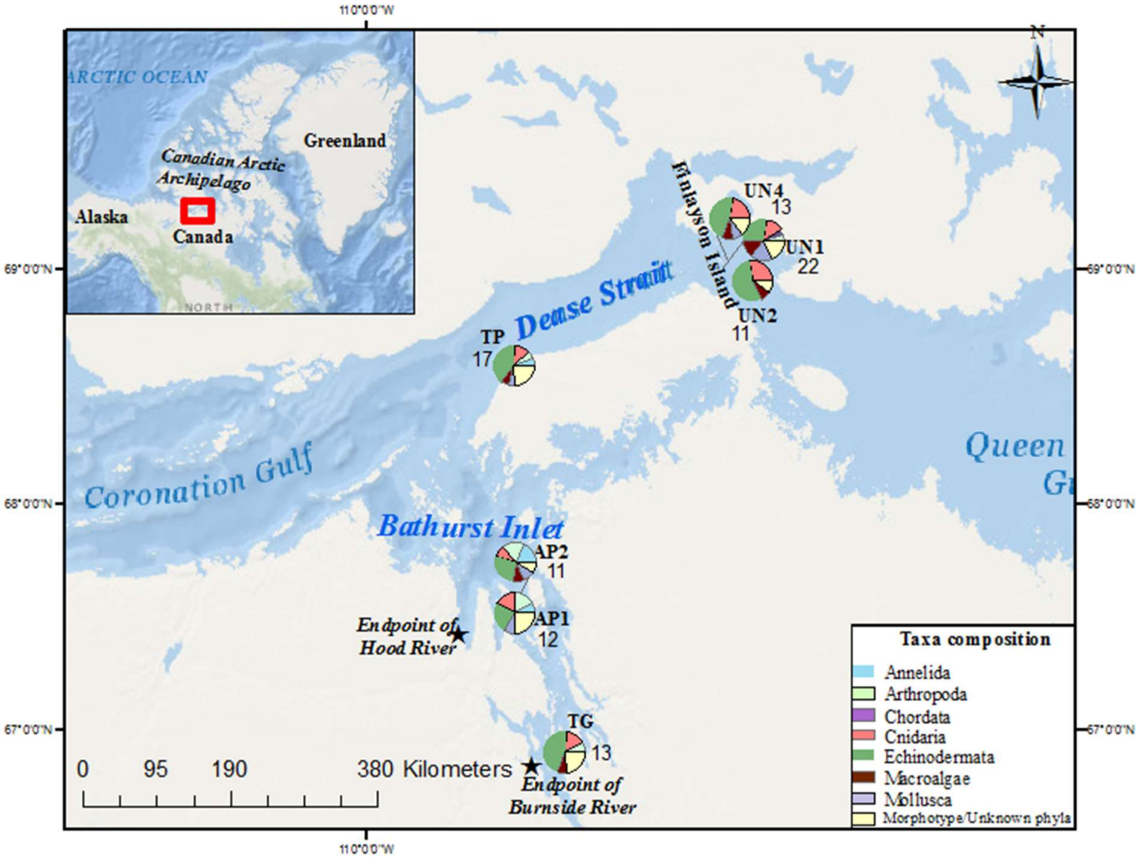


Figure 13: The pie charts in the map represent taxonomic composition of epibenthic invertebrates that was recorded from seven station with use of imagery analysis. Images were collected in the Kitikmeot Sea in Canadian Arctic Archipelago as part of the Kitikmeot Marine Science study in august 2016. Number close to the pie charts indicate the taxa richness at each station, where the highest taxa richness was recorded at station UN1. Red algae (Rhodophyta) and brown algae (Ochrophyta) were combined as macroalgae.

4.2.4 Epibenthos abundance and variability along station transects

The estimated mean abundance at stations varied from 4.6 ind. per m^2 at the transitional site station TG to 208.7 ind. per m^2 at the low flow station AP2 (48.8 ± 72.2 ind per m^2) (Figure 14A). The low flow stations (AP1 and AP2) were by far dominated by Ophiuroidea in abundance (Figure 14A, Figure 14B). The transitional site stations were dominated by Holothuroidea (TG) and Ophiouroidea (UN4) and at the high flow stations Crinoidea and red algae (TP), Cnidaria and Ochrophyta (UN1) and Holothuroidea (UN2), dominated (Figure 14A, Figure 14B).

Along each station transect abundance changes from the beginning of the station transect towards the end. Estimated abundance for each picture along station transect at the low flow sites varied between 17.7 – 70.2 ind. per m^2 for AP1 (Figure 15A) and 97.6 – 330.0 ind. per m^2 for AP2 (Figure 15B). Both stations had no changes in taxa dominance and Ophiuroidea dominated throughout both station transects. The taxa that made station AP1 differ from AP2 were the unidentified morphotypes that regularly occurred at AP1.

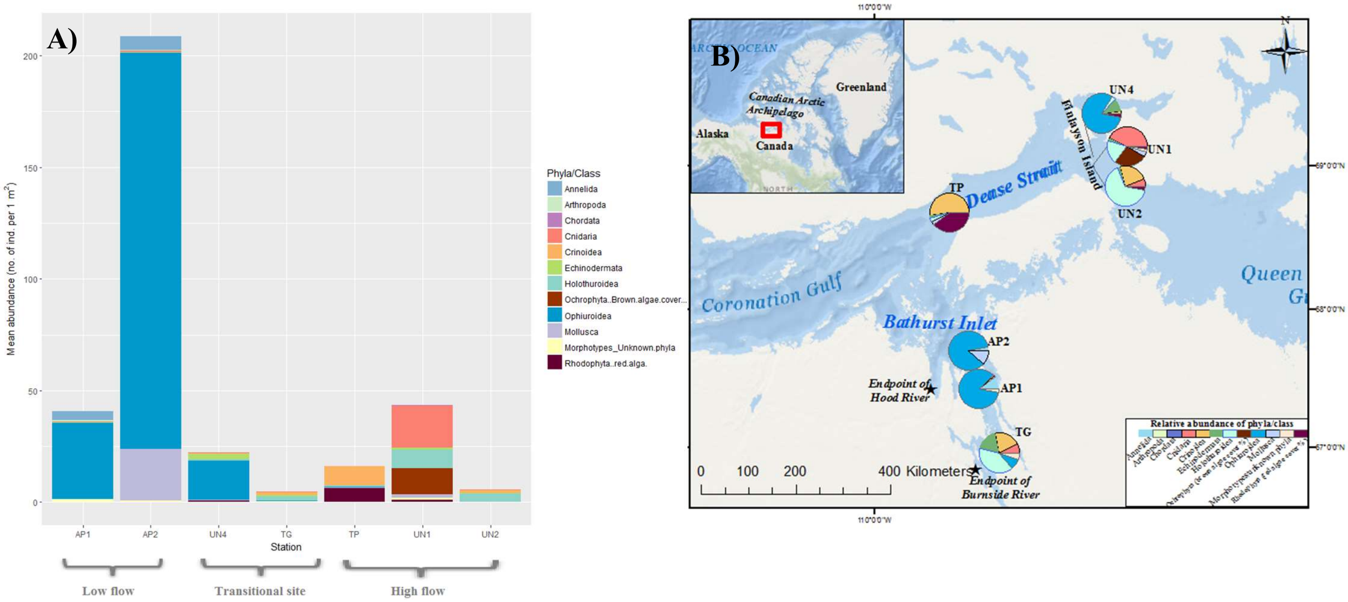


Figure 14: Abundance and taxonomic composition of epibenthos that was recorded in images that were sampled at seven station in the Kitikmeot Sea in Canadian Arctic Archipelago. The phylum Echinodermata in the legend consists of other taxonomical groups which were not that abundant (i.e. Echinoidea, Asteroidea). **A)** Mean abundance (no. of ind. per m^2), where the stations are sorted after low flow, transitional site and high flow, **B)** relative composition of phyla/class depited in map.

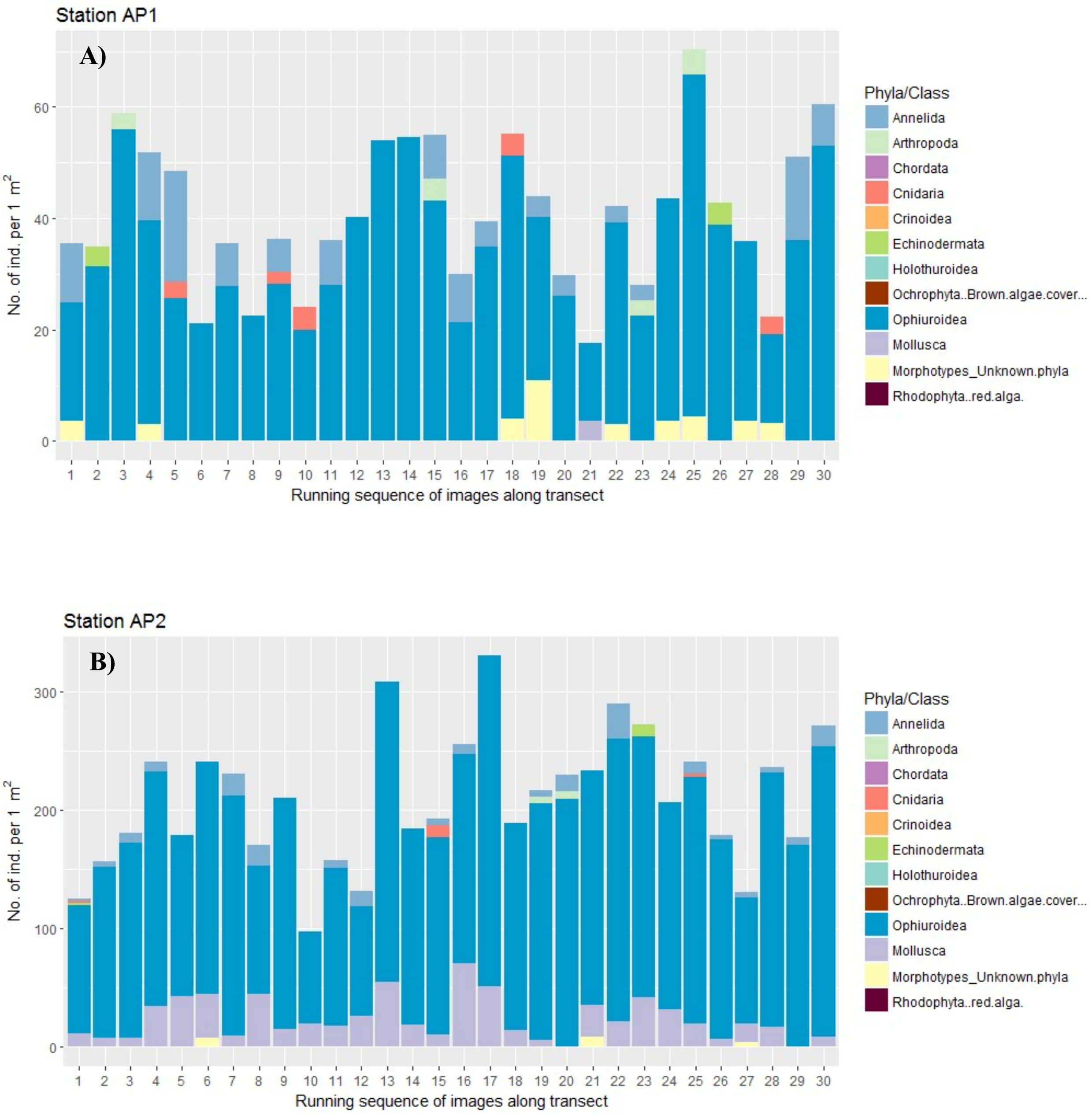


Figure 15: Running sequence of images that were taken at two low flow sites in the Kitikmeot Sea in August 2016 and depicts how many organisms within a phylum or class were estimated in each photo (m^2). The phylum Echinodermata in the legend consists of other taxonomical groups which were not that abundant (i.e. Echinoidea, Asteroidea). **A)** Station Algak Passage 1 (AP1), which was mostly dominated by ophiuroids and **B)** station Algak Passage 2 (AP2), also highly dominated by ophiuroids.

The two transitional sites were not closely related in terms of geographic distance (Figure 11), but were both characterized by mixed sediments with a transition between mostly soft and more hard substrate. Taxonomic dominance in abundance varied for both stations along the transect. The transition station UN4 had an estimated abundance along the transect that varied between 1.4 – 62.6 ind. per m^2. Echinodermata, Crinoidea and Holothuroidea as well as red algae were present in the beginning of transect and became close to absent towards the end of the transect when high abundance of Ophiuroidea was to be encountered (Figure 16A). The estimated abundance for the images at station TG varied from 1.1 – 11.4 ind. per m^2. Here, red Holothuroidea was the most abundant taxon throughout the first half of the station transect, while the second half had more variable taxonomic composition, and Crinoidea occurred throughout the transect (Figure 16B). In general, the number of taxa per image was low at TG (13 taxa), which also applied to the abundance of organisms at the site. Also, the Echinodermata (consists of Asteroidea and Echinoidea) were present on the images together with Cnidaria and Ophiuroidea.

There was also variation in abundance and taxonomic composition along transects at the high flow stations. The estimated abundance along transect for station TP varied between 4.4 – 31.7 ind. per m^2. Mainly Crinoidea and red algae (Rhodophyta) were dominating along transect with the red algae being particularly abundant in the second half of the transect (Figure 17A). Other taxa were also found (e.g. Anthozoa, Decapoda), but were not main contributors of the abundance in the images. Station UN1 had an estimated abundance along the transect that varied between 16.0 – 101.0 ind. per m^2, where most of the counts represented taxa in the phylum Cnidaria (e.g. *Gersemia*-like soft coral white), with high abundance in particular in the latter two thirds of the transect. Holothuroidea was also a taxon that was frequently observed in the images along the transect (Figure 17B). Brown macroalgae (Ochrophyta) mainly dominated the images in the beginning of the transect at station UN1, but decreased towards the end. The third high flow station (UN2) had low estimated abundances along the transect which varied between 0.9 – 29.3 ind. per m^2. No brown algae (Ochrophyta) were present, but instead, Crinoidea dominated the seafloor in the beginning of the transect (Figure 17C) and was observed to be horizontally positioned due to the high current velocities at the site. A mix of two different Holothuroidea was present at the station, where one Holothuroidea taxa was more abundant in some images than the other, and *vice versa.* Red algae and Asteroidea (Echinodermata) were also present at this station.

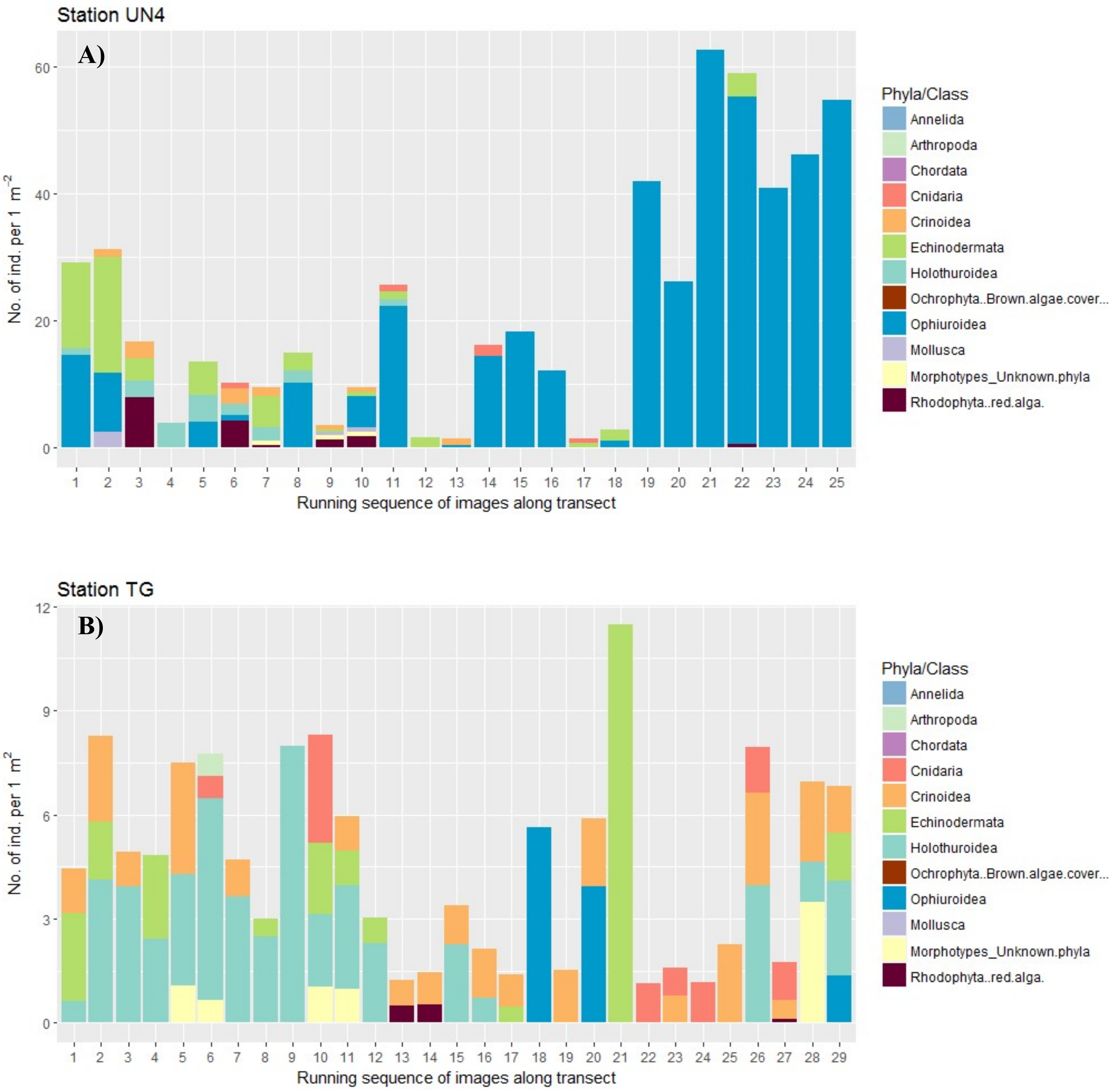


Figure 16: Running sequence of images that were taken along a station transect at two transitional sites in the Kitikmeot Sea in August 2016. Panels depict how many organisms within listed the taxonomical groups were present on each image which was cropped to m^2. The phylum Echinodermata in the legend consists of other taxonomical groups which were not that abundant (i.e. Echinoidea, Asteroidea). **A)** Station Finlayson Island (UN4) and **B)** station Tinney Gate (TG).

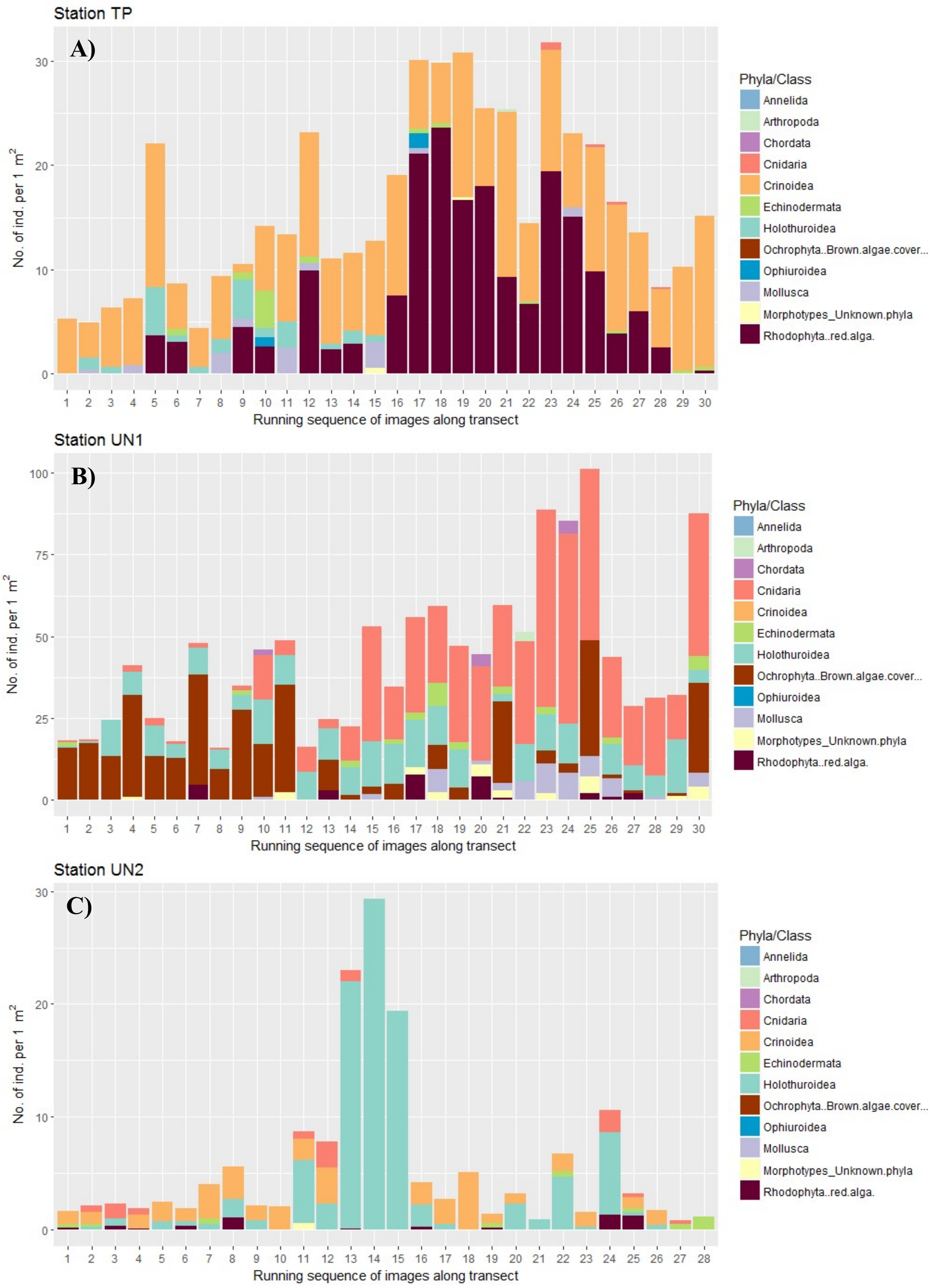


Figure 17: Running sequence of images that were taken along a station transect at three high flow sites in the Kitikmeot Sea in August 2016. Panels depict how many organisms within listed the taxonomical groups were present on each image which was cropped to m^2. The phylum Echinodermata in the legend consists of other taxonomical groups which were not that abundant (i.e. Echinoidea, Asteroidea). **A)** Station Turnagain Point (TP), **B)** Station Finlayson Island (UN1) and **C)** station Finlayson Island (UN2).

4.2.5 *Feeding strategies at different sites*

A total of six different feeding categories were assigned to the taxa that were present in the images (Figure 18). The overall distribution of feeding strategies in the study region can be seen in Figure 18A, Figure 18B. Not defined (n.d) belonged to all the unidentified taxa and morphotypes, but still did not account for a large proportion because there were low abundances of morphotypes in the study area. Surface deposit feeders mainly dominated at the stations with low flow and suspension feeders were more prominent at high flow sites. One of the transitional sites (UN4) closely resembled the low flow sites due to similar feeding strategies that were highly abundant at these sites (Figure 18A, Figure 18B). Additionally, the other transitional site (TG) resembled more the high flow sites because of a dominance of suspension feeders. Grazers and primary producers were more common at the shallow sites were light occurred, but were also present at the deepest station (e.g. Patellogastropoda). Predators were less prominent and did not account for a large amount in abundance. Some fish and shrimps (i.e. large motile taxa) may have escaped from the images, but despite this bias, predators are always lower in number (Lindeman 1942).

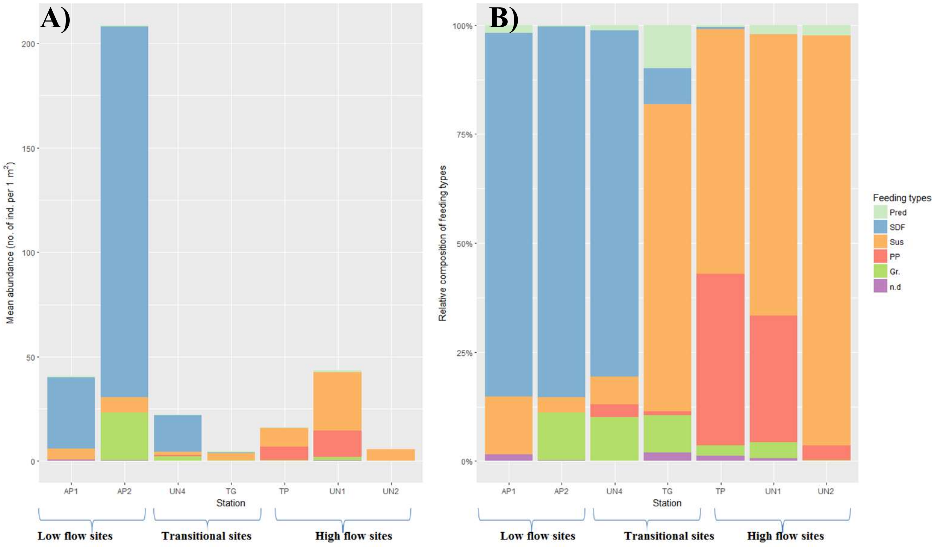


Figure 18: Epibenthic feeding strategies that were represented on the images that were taken in the Kitikmeot Sea in August 2016. The abbreviations for the different feeding types are: **Pred** = predator and scavengers, **SDF** = Surface deposit feeder, **Sus** = Suspension feeder, **PP** = primary producer, **Gr.** = grazer and **n.d** = not defined. **A)** Mean abundance of feeding strategies per m^2 and **B)** relative composition of feeding strategies.

4.2.6 Spatial pattern in epibenthic communities

Based on advices and suggestions how to treat the data set in the most suitable way, both Gower similarity coefficient (S15) and the Bray-Curis similarity matrices were attempted to use in the statistical analysis to see if it provided any explanatory pattern. Both ANOSIM results are depicted in Appendix Table 4. However, the Bray-Curtis similarity with square-root abundance-based data were used for ordination of the stations and for a further ANOSIM test in this study. The factors habitat type (low flow, transitional site and high flow) were tested and did not show a statistically significant difference between the current regimes in the study region (ANOSIM, global $R = 0.6$, $p = 0.57$), where the global R suggested a separation between the sites.

Only two clusters in the dendrogram for hierarchical cluster analysis were statistically significant different (SIMPROF analysis with $\alpha = 0.05$) (Figure 19A). Ordination of the stations with biological abundance-based data were depicted in Figure 19B to try to explain the spatial pattern in epibenthic communities. Geographical setting of the clusters can be seen in Figure 19C.

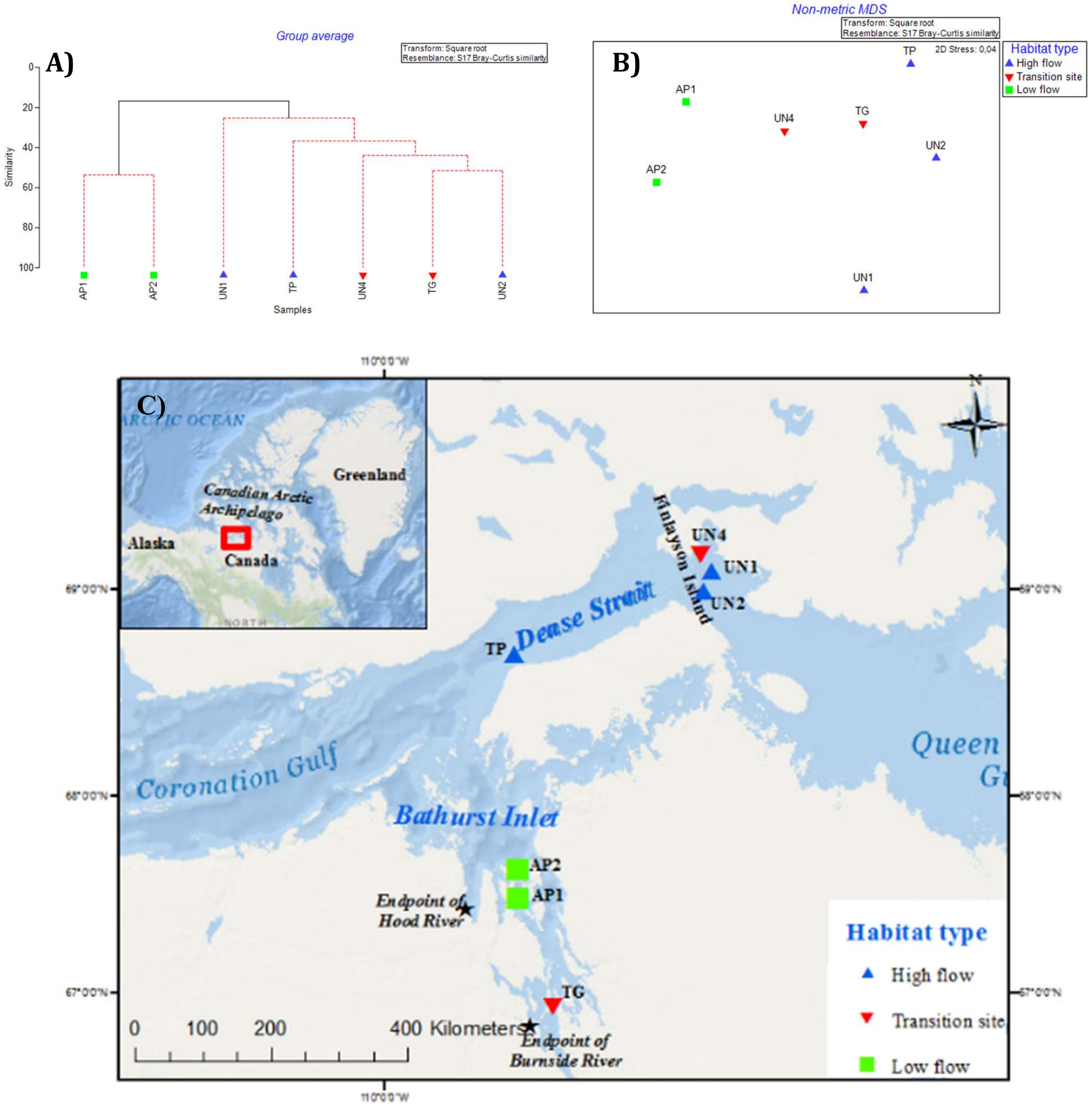


Figure 19: Station similarities where the stations are grouped by habitat type low flow, transitional site and high flow. **A)** Station clusters that were obtained from the hierarchical cluster analysis with square-root transformed abundance-based data and Bray-Curtis similarity matrix, **B)** nMDS plot of the abundance-based data and **C)** ordination of the station that were grouped in the different habitat type cluster.

5 Discussion

5.1 Methods discussion

5.1.1 Sampling methods used in this study

Several gear types can be used to study and gather information about epibenthic communities. It is difficult to choose the most suitable sampling gear since every tool has their specific advantages and limitations (Jørgensen *et al.,* 2011). These advantages and disadvantages lead to trade-offs in terms of sampling, and are summarized in Table 11 for the gears that were used in this study. The large range of available sampling gears reflects that there are several ways to study epibenthic invertebrates, and the choice highly depends on the researcher's question and vessel capabilities. Different sampling gears do not perform equally well in all habitat types, with some tools constructed to rather perform well at soft bottom locations and others in rocky habitats (Buhl-Mortensen *et al.,* 2012). This variation in gear types used has made it difficult to compare results across studies which have used different gear types that exhibit different features.

In this Master's Thesis, three different gear types were used to study epibenthic invertebrates in two regions of the Arctic: A Campelen trawl and an Agassiz trawl were used in Northeast Greenland and underwater imagery was used in the Kitikmeot Sea in the Canadian Arctic Archipelago. The trawls are destructive, whereas the underwater imagery sampling procedure is a non-destructive sampling technique (Eleftheriou and McIntyre 2005). These gear types provide either qualitative (Agassiz trawl), semi-quantitative (Campelen trawl) or quantitative (underwater imagery, when scaled) information (Eleftheriou and McIntyre 2005).

The Campelen trawl is considered a semi-quantitative sampling tool when sensors attached to the trawl are recording bottom time of the trawl (Eleftheriou and McIntyre 2005) and when ship speed is known. It is designed to target shrimps in commercial fisheries (Walsh and McCallum 1997), but also catches non-target species. Trawling is a common sampling tool used in scientific studies for surveying large areas of seabed communities (Jørgensen *et al.,* 2015a; Jørgensen *et al.,* 2015b). However, scientific research based on trawling has its drawbacks. Several studies have described the negative influence trawling has on epibenthic communities and non-target species (Jennings *et al.,* 2001; Puig *et al.,* 2012; Christiansen *et al*., 2014). Trawling causes physical damage to the seabed, with slow growing and sessile organisms (e.g. sponges and corals) being the most exposed to destruction (Garcia *et al*., 2007; Jørgensen *et al.,* 2015b). Deep-water corals for example, such as *Lophelia pertusa,* grow only 0.5 – 2.5 mm yr^{-1} and it will take decades to centuries to recover in large areas that have been exposed to trawling (Garcia *et al.,* 2007).

Compared to the Campelen trawl, the Agassiz trawl is a less selective tool. The Campelen's selective construction might be the reason to why the polar shrimp *Lebbeus polaris* were marked as present at all stations where Campelen trawl was deployed. The shrimps *Sclerocrangon ferox* and *Sabinea septemcarinata* were also highly frequent in the Campelen trawl catches. For the Agassiz trawl, it is documented that highly motile species such as shrimps and fishes are not caught efficiently and the Agassiz trawl is, hence, not used as a commercial sampling tool in fisheries (Eleftheriou and McIntyre 2005). Instead, the Agassiz trawl is used in surveys to collect epifaunal invertebrates (Eleftheriou and McIntyre 2005). Because of the trawl's qualitative rather than quantitative attribute due to inconsistent bottom contact related to collecting epibenthic invertebrates, its purpose in this study was to collect specimens for taxonomic identification and to confirm the species' presence and relative occurrences in the trawled area.

Underwater imagery is the third method used in the master's thesis and was applied in the Kitikmeot Sea, CAA. The advantages of performing photographic studies is that it is possible to perform environmental assessments and *in situ* observations at the same time as collecting epifaunal community data (Flannery and Przeslawski 2015). When trawling is conducted in a large area, it is not possible to detect exactly where the species were found, or which type of habitat feature it was associated with. Small-scale resolution of epifaunal distribution patterns, however, is possible when conducting surveys with underwater imagery. The most obvious disadvantage of photographic methods is their inability to collect physical specimens for confirmation of species identity.

Table 11: Advantages and disadvantages of using a Campelen 1800 shrimp trawl, an Agassiz trawl and underwater imagery to study epibenthic invertebrates (Eleftheriou and McIntyre 2005; Flannery and Przeslawski 2015; pers. obs).

Sampling gear	Advantages	Disadvantages
Campelen 1800 Shrimp trawl	- Indications on how much/many are found per unit area (semi-quantitative)	- Destructive to seafloor and can damage the organisms caught
Agassiz trawl	- Confirm species presence - Physical taxonomic specimen	- No quantitative information - Destructive and can damage the organisms caught
Underwater imagery	- No physical damage - *In situ* observations possible - Abundance estimates can be performed when scale is present	- Turbidity can make it difficult to detect species in the image - No physical specimens can be collected - Confirming species identity in image may be difficult

5.1.2 Data acquisition, design and possible biases in study of NEG

Since few stations were visited during each individual TUNU expedition, it was therefore considered appropriate to pool the data sets from the different years into one data set to detect an overall pattern in the study area. However, there were some inherent issues regarding the sampling techniques, which might have affected the data set for this study and these are mentioned in this section.

Different field teams participated in the two expeditions, and their different levels of taxonomic knowledge resulted in inconsistent taxonomic resolution between the years in some cases. This problem was in part mitigated through an extensive voucher collection for almost all taxa collected including challenging ones such as Amphipoda and Porifera. The vouchers were used in the lab the univeristy to improve field identifications and ensure consistency. Not all taxa were, however, vouchered at each station leaving uncertainty. When sponges were caught physically, they often get damaged which makes it even more difficult to identify without any taxonomic expertise.

Samples of sediments were taken in the vicinity of the trawl stations, hence, not representing the sediment composition at exactly the stations. Additionally, when the trawl covers a large geographical area it can trawl over a heterogeneous substrate. In contrast, the box core records the sediment grain size over a small area and a single sample within the trawl track does not capture potential heterogeneity. For example, the trawl jumped occasionally on the seafloor at the bank station 1346-TUNUVII, which indicates a hard bottom with perhaps drop stones, but the box core sampled sediment where the proportion was 1.03 % sand and 98.97 % mud (Table 1). Additionally, sediment grain size percentages were only gathered for the TUNU-VII (2017) expedition only since many box cores failed to collect sediment due to rocky bottom. Therefore, the sediment grain size percentages were not included in the PCA, but could have changed the grouping of the stations since it is known that sediment has shown to be an important characteristic that structures epibenthic communities in the Arctic (Mayer and Piepenburg 1996; Bluhm *et al.,* 2009).

Another issue with trawling time was observed, where trawling time varied between stations, within and between gears (e.g. Agassiz trawling varied from 9 to 40 min). Uneven trawl duration likely makes the number of taxa incomparable between stations and locations, at least for the rare taxa since the probability of catching more taxa increases with trawling duration. Therefore, comparison of taxon richness between locations is somewhat biased. However, common taxa that are present in the study area will not be affected.

The biggest issue with calculating trawled area is knowing the opening of the trawl which is one determinant in estimating area fished, and it was challenging to choose the most suitable calculation method. Several methods that can be used to calculate the abundance and biomass. Two options were considered for this thesis how to calculate the estimated abundance and biomass. The first method took into account that there was an affixed strap that gives a known maximum opening of the trawl (11.7 m) and hence possible to calculate the area trawled. Also, the width of the trawled path is determined by approximating the actual net width during fishing. In the absence of sensors on the wings that would measure the variation in the net opening, a fixed estimate of the approximate net opening was used in crab assessments by IMR; this approach was also applied in this thesis given the focus on invertebrates. The calculation of the trawl area based on an assumed fixed opening is not entirely the proper method to use either since there was a strap attached between the trawl doors, which constrain the opening to a maximum width, but not the variation during trawling. The strap kept the distance between the trawl doors approximately fixed as it is originally described in the manual for scientific trawling by IMR (Havforskningsinstituttet 2008). This approach was however, evaluated to be the most suitable method for this thesis. The second alternative method was based on the distance between trawl doors as is done for fish given they are chased into the net by the doors (J.S. Christiansen, UiT – The Arctic University of Norway, Tromsø, pers. comm.). This method was not chosen because benthic invertebrates are much less motile and will not be chased into the net in the same way as fish, which will overestimate the area trawled. Regardless of which calculation method is used, uncertain is inevitable in such estimates was also the case for snow crab assessments in the Barents Sea (Hvingel *et al.,* 2017).

5.1.3 Data acquisition, design and possible biases in study of the Kitikmeot Sea

All taxa that were present on the images were classified as epibenthic invertebrates even though some taxa (e.g. *Cerianthus* spp.) are partially within the sediment (Jensen 1992). I chose this approach to match earlier studies that had made the same choice (e.g. Mayer and Piepenburg (1996). Many issues were encountered during image analysis (see section 3.2.2 *Image collection, processing and analysis*) and were tried to be avoided to reduce the biases in this part of the study. The distance from the seafloor varied among stations and also within stations. The varying distance from the seafloor was most likely an important factor when identifying the taxa that were present on the images. When the camera was close to the seafloor, it probably scared the larger more motile organisms away, whereas the less motile (compared to fishes and crabs) and smaller organisms are present and highly visible. This might be the reason for why ophiuroids were detectable on the low flow sites where the camera could safely be deployed close to seafloor. In contrast, when the camera was far from seafloor, it was easy to see the larger epibenthos, such as crinoids, holothuroids and also crabs, but smaller epibenthos was difficult to see, especially with poor image resolution.

In this part of the master's thesis, only seven stations were sampled, which might be too few to be able to see a clear biological pattern. The issue arose when I realized that the statistical results differed based on the choice of the similarity matrix used (Appendix Table 3). I believe that more stations are needed to have greater statistical power since I did not detect any statistically significant differences between habitat types when Bray-Curtis similarity was used.

5.2 Northeast Greenland

5.2.1 Taxa composition

The taxa inventory of epibenthos in the study area of Northeast Greenland amounted to 276 putative species that were caught with Campelen and Agassiz trawls. The taxa inventory list in this study is generally comparable to that of other epifauna surveys on Arctic shelves (Table 12). However, it is important to take into account that these different studies have not used the same gear types, a fact that constrains the comparability of taxa gathered across studies. This applies of course for abundance and biomass comparisons also. A meta-analysis study by Piepenburg *et al*., (2011) suggests an estimate of between 3,900 – 4,700 macro- megabenthic species that are likely to be encountered on Arctic shelves. Predictive techniques in Piepenburg *et al*., (2011) show that a much larger sampling effort than performed in the Arctic so far is needed to account for all species that exists on Arctic shelves. The NEG shelf was poorly represented in this meta-analysis, and this thesis, therefore, improved the inventory list from this region. The taxa accumulation curve presented in this study suggests a more comprehensive sampling effort to collect all species in the region when both gears are used. Many of the taxa that were caught during this study are widely distributed throughout the Arctic (e.g. *Ctenodiscus crispatus, Gorgoncephalus* spp., *Lebbeus polaris*, *Ophiocten sericeum, Ophiacantha bidentata, Sclerocrangon ferox*, *Strongylocentrotus pallidus*) (Sirenko 2001; Vassilenko and Petryashov 2009). Furthermore, some common taxa were also found in earlier studies from NEG (e.g. *Ophiocten sericeum*, *Ophiacantha bidentata* (in Starmans *et al*., 1999; Mayer and Piepenburg 1996). Noteworthy, few specimens of *Ophiura sarsii* were caught along the shelf break during the TUNU-VI expedition in 2015, but did not occur at all in catches by Piepenburg *et al.,* (1997b) which had overlapping regions.

Table 12: A summary of different epibenthos surveys that have been conducted in the Arctic, namely in Northeast Greenland, Chukchi Sea, Beaufort Sea and Canadian Arctic Archipelago. The table shows number of taxa recorded, estimates of abundance range (no. of ind. per 1000 m^2), the dominant taxa by abundance, biomass range (g wet weight per 1000 m^2), which was recalculated, and dominant taxa in biomass. The number of stations covered and the gear type deployed are also given.

No. of taxa	**Abundance range No. of ind. per 1000 m^2**	**Taxa dominated in abundance**	**Biomass range g ww per 1000 m^2**	**Taxa dominated in biomass**	**Study area**	**Stations covered**	**Gear**	**Literature**
276	4.1 - 854.1	*Similipecten greenlandicus, Lebbeus polaris,*	65.0 - 527.7	*Gorgoncephalus* spp., *Similipecten greenlandicus*	Northeast Greenland	18	Campelen 1800 shrimp trawl (*40 mm mesh size in cod end*)	This study
165	229 - 70,879	*Ophiura sarsii, Chionoecetes opilio*	1,628 - 217,023	*Ophiura sarsii, Chionoecetes opilio*	Chukchi Sea	45	Plumb staff beam trawl (PSBT) (*4 mm mesh size in cod end*)	Bluhm *et al.*, (2009)
44	150 - 550,000	Ophiuroidea	57 - 645,000	Ophiuroidea	Chukchi Sea	53	Plumb staff beam trawl (PSBT) (*4 mm mesh size in cod end*)	Ravelo *et al.*, (2014)
133	40 - 275,590	*Ophiura sarsii*	58 - 501,031	*Ophiura sarsii, Gorgoncephalus* spp.	Beaufort Sea	71	Plumb staff beam trawl (PSBT) and modified plumb staff beam trawl (PSBT-A) (*4 mm mesh size in cod end*)	Ravelo *et al.*, (2015)
527	1000 - 382,000	-	30 - 77,100	Ophiuroidea	Canadian Arctic Archipelago	78	Agassiz trawl (*5 mm mesh size in cod end*)	Roy *et al.*, (2014)

The most taxa rich phylum in NEG was Arthropoda, which accounted for 73 taxa identified. Many more species of arthropods exist in NEG waters since 200 species that belong to the superorder Peracarida alone have been recorded (Brandt 1997). Similarly, another Arctic study by Sirenko (2001) has also shown that Arthropoda is the most taxon rich phylum, which is highly probable since there more than 1,500 species of only Amphipoda are recorded in Eurasian Arctic seas (Sirenko 2001).

For the phylum Porifera, there are few records on how many species have been found on the NEG shelf. In the beginning of the 1900s there were 54 species of sponges in the inventory list (Burton 1934), and only 28 species from the taxonomical group Calcarea were described in Rapp (2015). The species number is probably much higher today since there have been continuously records on new Porifera species in NEG (e.g. Burton 1934; Rapp 2015). In this study, Porifera was the second most taxon rich phylum and represented 17 % of the total taxa caught in both trawls, while in Starmans *et al.,* (1999) who worked even further north on the NEG shelf, the same phylum even contributed to the highest taxa richness. Studies in the Arctic have acknowledged that identification of Porifera is very challenging leaving often sponges with unidentified names at phylum level (e.g. Jørgensen and Gulliksen 2001). Porifera individuals from the same species can exhibit variation in shape, morphology, length and width, and different sizes on the pores (even within the same colony) (Klitgaard and Tendal 2004; Manconi *et al*., 2009), making it rather hard to determine to a lower taxon level. There are records of large sponge communities along the NEG shelf break and at the slope (Mayer and Piepenburg 1996; M. Sejr, Aarhus University, pers. comm.). These are thought to be ecologically important in that Porifera communities creates shelter and habitat for other species (Barthel and Brandt 1995).

Interestingly, both trawl types had similar mesh size, but the Agassiz however, caught more and smaller taxa than the Campelen trawl. A reasonable explanation for this difference is that the Agassiz trawl dug more into the sediment and caught also taxa that sit near the sediment surface. Though this study focused on epibenthic invertebrates and excluded known infauna, some taxa have part of their bodies on and part in the sediment, and for some their habitat preference is unclear or flexible.

5.2.2 Abundance and biomass

Different mesh sizes of gear types used across epibenthos studies in the Arctic limit the comparisons with other studies performed in the Arctic. However, previous records on abundance and biomass in the (Table 12) suggest that abundance and biomass in this study were extremely low. A large part of this marked difference may be explained by the large mesh size used in this study compared to the referenced studies. Another part of the reason, however, might be related to the high productivity in the water column in the Pacific-influenced Arctic (Grebmeier *et al.,* 2006a) that rapidly sinks to the seafloor providing favorable conditions for benthos and therefore high abundances and biomass.

Throughout the study region, Echinodermata was the phylum that contributed most to abundances and biomasses at many stations. Similarly, several earlier studies conducted on Arctic shelves have found that especially ophiuroids can attain high densities (Mayer and Piepenburg 1996; Roy *et al*., 2014; Ravelo *et al*., 2015). One of the plausible explanations to high densities of echinoderms in the Arctic and polar environments in general is that they are highly motile benthos (e.g. Ophiuroida) (Piepenburg 2000; Thistle 2003), which allows them to quickly respond to occasional food patches at the seafloor (Iken *et al*., 2001). In this study, ophiuroids (e.g. *Ophiacantha bidentata, Ophiopleura borealis*) were frequently present throughout the NEG region and their abundance and biomass were particularly prominent inside the fjords and at Belgica Bank, respectively. Besides ophiuroids, a substantial biomass of the holothuroid *Molpadia borealis* that exhibits a deposit-feeding feeding strategy (Barnes 1982) was found inside Bessel Fjord. This occurrence may be linked with the high abundance of terrestrial and macroalgal debris in the fjord since sinking organic materials provides food to epibenthic communities. Holothuroids in particular, have been shown to positively correlate with organic carbon flow (Iken *et al*., 2001). Additionally, high abundance of the deposit-feeding asteroid *Ctenodiscus crispatus* (Shick *et al*., 1981) located in the mouth of Bessel Fjord could be related to the large amounts of sinking marine snow that was recorded there (F. Norrbin and T. Beroujon, UiT – The Arctic University of Norway, Tromsø, pers. comm.). *Ctenodiscus crispatus* also dominates abundance further north on the NEG shelf (Piepenburg *et al*., 1997b) and has been found in several Arctic Seas, except the White Sea in the Eurasian Arctic (Sirenko 2001).

The station located at Belgica Bank (1365-TUNUVII), had high densities of echinoderm larvae in the water column (F. Norrbin and T. Beroujon, UiT – The Arctic University of Norway, Tromsø, pers. comm.) during the TUNU-VII expedition in September 2017, which can indicate that there were favorable conditions for mass production of echinoderms during this season. The high abundances of echinoderms were also reflected at the seafloor at the same station, where there were high abundances of *Ophiopleura borealis* at the bank. Additionally, other taxa within other phyla (*Sabinea septemcarinata* and some Pycnogonida) were carrying eggs at this station, also indicating that conditions were favorable for epibenthic invertebrates to reproduce.

The crinoids *Heliometra glacialis* and *Poliometra polixa* contributed largely to the abundance inside Dove Bugt (station 1316-TUNUVII) during the study. Especially *Heliometra glacialis* is a species that is widely distributed on Arctic shelves (Sirenko 2001), found in high densities and biomasses around Svalbard, and creates nursery areas for fish and shelter for other organisms (Jørgensen 2017). Crinoids are heavily damaged in trawls and the biomass of the species are hence, often underestimated (Jørgensen 2017), which was the case for this study since few organisms had all body parts intact. They could have then contributed a larger amount to station biomass. *Gorgoncephalus* spp. was the taxa that contributed to the largest amount of biomass at same station. Even if few specimens of *Gorgoncephalus* spp. are caught, they often contribute to a large proportion to station biomass since a single individual has high body weight (Jørgensen 2017).

Arthropoda was another phylum that was particularly prominent in terms of abundance. Two out of five shelf stations had Arthropoda as the major contributor to abundance, where *Lebbeus polaris* and *Eusirus* spp. dominated at station 1338-TUNUVII and 1354-TUNUVII, respectively, but the abundances were not as high compared to the 76º N bank station located at the shelf 1346-TUNUVII. Another study conducted on a Pacific-influenced shelf in the Arctic in Chukchi Sea has shown that the snow crab (*Chionoecetes opilio*) (Arthropoda) was dominating in both abundance and biomass (Bluhm *et al.,* 2009). Noteworthy, only one small single specimen of the crab *Hyas* sp. in this study, which is a big contrast to what was caught in catches of crabs. Further out towards the shelf break stations, two out of seven stations were dominated by Arthropoda, the major contributor to the abundance at the stations. The arthropods *Sabinea septemcarianta* and *Lebbeus polaris* dominated at station 1375-TUNUVII and 1312-TUNUVI, respectively. A similar study conducted with underwater imagery analysis at same conditions along the NEG shelf break did not find high abundances of Arthropoda (Mayer and Piepenburg 1996) and can be related to that they can be scared by the camera. The stations located at the slope were dominated in abundance by *Lebbeus polaris* and *Pasiphaea* *tarda* at stations 1307-TUNUVI and 1345-TUNUVI, respectively. Of all the mentioned arthropod taxa caught in the trawls that contributed to high abundances, mostly of them were shrimps and might be related to the Campelen's selectivity, which was discussed previously (*5.1.1 Sampling methods used in this study*).

The single species *Similipecten greenlandicus* a filter-feeding (Hobson *et al*., 1995) bivalve, occurred only at location (1346-TUNUVII and 1349-TUNUVII), but were the species that contributed most to the station with the highest biomass. This species prefers hard bottom to grow and it is known from another study that it can aggregate in high densities (Ravelo *et al.,* 2015). In contrast to *Similipecten greenlandicus* that only occurred at one station, *Lebbeus polaris* were present at all Campelen trawl stations. This species is widely distributed throughout the Arctic and has been recorded on all Arctic shelves (Sirenko 2001) and has a "high boreal Arctic circumpolar" distribution (see Vassilenko and Petryashov 2009).

5.2.3 Relating environmental parameters to epibenthic communities in NEG

Four separate epibenthic community types were defined in the study area of NEG based on geographical features and exposure to environmental parameters in vicinity. Other community structure studies conducted in the Arctic also showed that environmental variables explain part of the variability in epibenthic communities from one station or region to another (e.g. Bluhm *et al.,* 2009; Ravelo *et al.,* 2015). This study gathered information in the Greenland Sea on epibenthic communities during late summer in 2015 and 2017 and the environmental conditions measured in the field represent only a snapshot and may fluctuate throughout the year and between seasons. The results presented here indicate that there is a significant difference in epibenthic communities from inner-fjord in Bessel Fjord towards the shelf break and slope. The observations and statistical analyses that have been performed show that epibenthic communities differed across habitat types and it will further be discussed if the collected environmental parameters from the both TUNU expeditions are the drivers to changes in community structure.

5.2.3.1 Bessel Fjord communities

The sills and basins located inside Bessel Fjord are maintaining relatively isolated systems. Contradictory to this observation, the epibenthic invertebrates that were collected at the different stations in the fjord had however, relatively similar biological assemblages (45.4 %). The observed similarity within the Bessel Fjord community can be related to the small sampling effort. The three stations in Bessel Fjord were characterized by the influence of particularly high turbidity, low bottom salinity and relatively high bottom oxygen concentrations. Fjords in the Arctic can be highly exposed to ice scouring, high sedimentation rate and melting glaciers that change the environmental conditions and hence, determine epibenthic community compositions (Holte and Gulliksen 1998; Conlan and Kvitek 2005), and can be the reason why Bessel Fjord had differently environmental variables compared to the other communities. Glacial sedimentation, ice scouring and physiological stressors such as low salinity are the main attributes that often contribute to a reduction in taxa richness, abundance and biomass in Arctic fjords (Görlich *et al*., 1987; Holte and Gulliksen 1998; Sejr *et al*., 2000; Włodarska-Kowalczuk *et al*., 2005; Włodarska-Kowalczuk *et al*., 2012), and it was therefore anticipated to find low taxa richness in Bessel Fjord. Instead, results showed rather high taxa richness. Melting glaciers enhance the turbidity in the water column and provide inorganic sediment to the seafloor and can smother and clog the filter-feeding organs of filter-feeding organisms (Moore 1977; Hall 1994; Włodarska-Kowalczuk *et al*., 2005). Yet, suspension feeders, such as *Styela* spp. and some Porifera were found in the two innermost fjord stations which indicates that the sedimentation conditions were still inhabitable, while another study in a fjord with high sedimentation found a reduction in filter-feeders (e.g. Włodarska-Kowalczuk *et al*., 2012).

The station located at the mouth of Bessel Fjord was characterized by warmer (and more saline) waters compared to the two innermost stations, but it still had high turbidity. The epibenthic fauna at the mouth of the fjord was somewhat similar to the two other stations located further in the fjord, where the amphipod *Anonyx* spp. was not confirmed as present. This can be related to the presence of warm water as this species inhabits rather cold water environments (Sainte-Marie *et al.,* 1989). A fjord with a sill located at the mouth, which was the case for Bessel Fjord, will to a larger degree prevent exchange of water masses (e.g. van Mijenfjord at Svalbard, Renaud *et al.,* 2007). The fjord will therefore be will be less susceptible to environmental variability, can could be therefore why *Anonyx* sp. was found in the colder environment of Bessel Fjord.

Insightful in terms of food supply was the occurrence of terrestrial plant leaf materials and macroalgal deposits on the seafloor in the innermost parts of Bessel Fjord. The terrestrial plant material, also known as willow plant *Salix* spp. was probably a local source that provided the marine environment with organic-rich materials, since it is known to grow in the surrounding environment (J.S. Christiansen, UiT – The Arctic University of Norway, Tromsø, pers. comm.). Relatively high abundance of the deposit-feeders *Molpadia borealis* and *Ophiopleura borealis* may be related to the described variety of organic debris that was found at the fjord stations, where deposit feeders will probably take advantage of the material after bacterial degradation. This supports the evidence of Renaud *et al.*, (2015) that macroalgal detritus and other carbon sources are important components supplied to benthic communities besides deposited phytoplankton. Unfortunately, only one food proxy (integrated chl *a*) was actually measured in this study to try to understand if food supply was structuring the epibenthic invertebrates. Since this study could only provide a snap shot in time, the chl *a* data are inconclusive in explaining community structure patterns. Similarly, other studies in the Arctic have included several food proxies (e.g. chl *a* in water column, total organic content in sediment) to try to explain the community structure but did not accomplish to explain community patterns either (e.g. Bluhm *et al.,* 2009; Roy *et al.,* 2014). However, there is a strong evidence that food supply determines abundance and biomass levels (e.g. Grebmeier *et al.,* 2015).

Sediment properties were only evaluated for the TUNU-VII expedition, where the majority of the sediment inside the fjords mostly consisted of mud (Table 1). The sediment in Bessel Fjord coincided with a dominance of taxa that mostly exhibited a deposit-feeding strategy, but also filter-feeding organisms were found. Bessel Fjord communities in contrast to other Arctic fjord communities are probably not as highly exposed to sedimentation and ice scouring as first thought.

5.2.3.2 Shelf communities

The five stations located at the NEG shelf were distributed over a large geographical area and exhibited a station similarity in taxa composition of 40.2 %. Within the study region, there was substantial habitat heterogeneity that consisted of troughs and banks with distinctive geomorphological features (Laberg *et al.*, 2017), which is an important factor when considering variability in epibenthic communities. In addition, hydrographic features along the NEG shelf have been shown to structure epibenthic communities in other studies (Piepenburg and Schmid 1996a; Piepenburg *et al.*, 1997a) and seem to do the same in this study as well. Four out of five shelf stations were closely grouped together based on similar water mass properties (Figure 10), with the majority of the stations influenced by relatively high temperatures (Table 1). Previous studies conducted in the same region suggest that the positive ocean water temperature originates from Atlantic water masses and from the WSC (Piepenburg and Schmid 1996a; Schneider and Budéus 1997). The occurrence of the deep-water shrimp *Pandalus borealis* caught only at station 1338-TUNUVII with relatively high biomasses supports the findings of warmer oceanic water that originates from the WSC. DNA-sequencing conducted on these shrimps confirms that they originate from the west coast of Spitzbergen and that they were probably advected by the currents to Greenlandic waters (A. Andrews, UiT – The Arctic Unuversity of Norway, Tromsø, pers. comm.).

The shallowest stations of all sampled in the study region (1346-TUNUVII, 65 m) was located at a bank along the 76° N latitude. This station was environmentally distinct compared to the others since it was characterized by high bottom oxygen content, temperatures below zero and the lowest salinity in the entire study area, as well as high turbidity (Table 1). While this shallow bank station was biologically largely similar to the other shelf stations, it had specific faunal species that made it noteworthy. Presence of the ice-associated amphipod *Gammarus wilkitzkii* can indicate that this area had recently been covered by sea ice. This amphipod is known to be able to cope with hypo-osmotic stress such as changes in salinity, which is often the case beneath the sea ice (Aarset and Aunaas 1987). *Gammarus wilkitzkii* were also found on the shelf station 1354-TUNUVII which could also indicate that sea ice could be encountered in the vicinity.

The total abundance and biomass at this shallowest shelf station 1346-TUNUVII were exceedingly higher than at all the other stations, with filter-feeding bivalves as the main contributor to the high numbers. It is speculated here that vertical mixing of organic material produced in the nearby NEW polynya (Ambrose and Renaud 1995; Piepenburg *et al.,* 1997a) gets advected southwards with the EGC and passes the bank stations, hence providing favorable conditions for *Similipecten greenlandicus*. Furthermore, the transport provides both oxygen- and nutrient rich water to the areas, which may be an additional explanation to high dominance of the bivalve. These ideas are supported by the assertion of Grebmeier and Barry (1991) that horizontal transport of organic matter can have a larger impact on abundance and biomass than vertical flux. Feder *et al*., (1994) also found high standing stocks of benthos, in the Pacific-influenced Arctic, which were, related that to advection of food supplies from other productive areas. Piepenburg and Schmid (1996a) performed a complementary study in NEG and suggested that existing organic carbon at bank locations originates from the NEW polynya further north and highlight its importance to the surrounding environments. This may also be case for the station located at Belgica Bank (1365-TUNUVII). Not only were abundance and biomass higher compared to other stations, the station also had the highest taxa richness recorded throughout the entire study region. The high taxa richness at banks can be related to a heterogeneous habitat, which provides a higher habitat complexity than pure soft substrates

(Buhl-Mortensen *et al*., 2012). Indeed, it was observed that the trawl was jumping occasionally on the seafloor at the bank station 1346-TUNUVII, which confirms that rocky habitats were also present in that area.

5.2.3.3 Shelf break communities

The shelf break stations had the lowest taxonomical similarity of all communities of 37.0 % and the highest amount of stations. A plausible explanation for the low taxonomical similarity is that the shelf break stations covered a large geographical range with different sediment categories, which was also found in Mayer and Piepenburg (1996). Geophysical records show evidence that the Greenland Ice Sheet stretched all the way out towards the continental shelf break in NEG during the last glaciated maximum (Laberg *et al*., 2017) leaving glacial traces on the seafloor. The deglaciation that occurred after the last ice age left ice-rafted drop stones at seafloor (Schulz *et al*., 2010) which created small-scale heterogeneity. This process is probably still occasionally taking place in today's Arctic when drifting pieces of glacial ice melt. In fact, there has been observed drop stones even at depths deeper than thousand meters in Fram Strait and Canada Basin, which increased the taxa richness on a local scale (MacDonald *et al.,* 2010a; Taylor *et al.,* 2016).

In addition to varying seabed features which was mentioned above, the distribution patterns of epibenthic communities along the shelf break at 75° N were in part also determined by temperature in an earlier study (Mayer and Piepenburg 1996). In agreement with this result, the findings from the present study also showed that shelf break stations grouped together (Figure 10) because of high bottom temperature probably coming from the intruding WSC that merges with the EGC at the shelf break (Bourke *et al*., 1987). Rather than concluding that temperature itself is a structuring factor, however, I suggest it is also the circulation-driven higher current velocities (Håvik *et al.,* 2017) and resulting coarser sediment compared to the adjacent shelf (in addition to the drop stones mentioned earlier), which creates a characteristic distinct environment inhabited by sessile filter feeders (Mayer and Piepenburg 1996; this study). Indirect evidence is given by the characteristics taxa of the shelf break community that included *Strongylocentrotus pallidus* and Crinoidea both of which typically occur on hard substrate. As a result of habitat heterogeneity, taxa richness can be higher at shelf breaks than on adjacent shelves (Mayer and Piepenburg 1996; Buhl-Mortensen *et al*., 2012; Ravelo *et al*., 2015). Similar to the shelf station 1338-TUNUVII, two of the shelf break stations had also presence of the deep-water shrimp *Pandalus borealis* that strengthens the evidence of Atlantic water reaching the Arctic NEG shelf and changing epibenthic taxa composition. The WSC that diverges from the west coast of Spitzbergen seems to connect the Atlantic biota with the biota found in Greenland Sea.

The above interpretation is supported by the fact that the geologists on board during TUNU-VI in 2015 found it challenging to conduct box core sampling due to rocky substrates at the shelf break, which resulted in only a small amount of successful box core samples (JS. Laberg, UiT – Arctic University of Norway, Tromsø, pers. comm.). Failing to collect these sediment samples during TUNU-VI in 2015 reflects that strong currents coming from north (Håvik *et al.,* 2017) are prevailing along the shelf break. Previous studies in the Arctic have documented that epibenthic communities are highly related to substrate type (Bluhm *et al*., 2009; MacDonald *et al*., 2010a; Yesson *et al*., 2015), since feeding strategies seem to change with differences in seabed features (Snelgrove and Butman 1995).

5.2.3.4 Slope communities

Changes in bathymetry and sediment features from the shelf break towards the slope can indicate drastic changes in community structure (Buhl-Mortensen *et al*., 2012). At slopes, these changes are particularly obvious, because depth can change fast and different communities occur (e.g. Mayer and Piepenburg 1996; Buhl-Mortensen *et al*., 2012). The slope communities in the study area had the highest taxonomical similarity of 48.7 %, which coincides with few taxa caught at only three stations. In addition to the biological similarity shown in the nMDS, the environmental variable depth was also an important factor that was grouping the stations together in the PCA (Figure 10). The temperatures at the slope stations decreased with increasing depth from shelf break and is often a signature that different water masses are lying on top of each other (Bourke *et al*., 1987). In-between the colder water masses, there is a layer that is more saline and warmer and can be traced as water from WSC (Schneider and Budéus 1997; Håvik *et al.,* 2017), so a change community structure down a depth gradient is logical when hydrographical factors are varying with depth.

Additionally, increasing depth coincides with a decrease in the amount of food particles that reaches the seafloor (Riser *et al.,* 2008). The findings in the present study with relatively low taxa richness and abundance (in two of three stations) may be related to decreasing food sinking down the depth gradient. In accordance to Mayer and Piepenburg (1996), however, there were high densities of sponges and corals at the shelf break and slope at 75 º N, which could not be confirmed by estimates from this study since biomass of colonial organisms was unfortunately not evaluated systematically in 2015. However, field notes written by scientists that joined the TUNU-VI in 2015 confirms that there were large amounts of sponges (approximately 15 kilo) at station 1347-TUNUVI. Large coverage of colonial sponges and corals creates shelter for other organisms (Barthel and Brandt 1995), which may explain why there was high taxa richness of amphipods at that same station 1347-TUNUVI.

Community slope and community shelf were the most dissimilar groups. The observed distinctiveness is related to the explained environmental variables as depth and dissimilarities in biological assemblages, leading to changes in epibenthic community structure, from one place to another. The ophiuroid *Ophiopleura borealis* were complete absent on the deep slope stations and quite abundant on the shelf. Previous studies in vicinity of NEW polynya also observed high densities of *Ophiopleura borealis* at the shelf (Gallagher *et al*., 1998). Interestingly, the pattern of where *Ophiopleura borealis* is present seem to vary, since Piepenburg *et al.,* (1997b) did not find them at all at Belgica Bank, but caught the species on the slope. *Pasiphaea tarda* was the species that was only found at the slope stations and is another biological variable that explains the differences between slope and shelf stations.

5.3 The Kitikmeot Sea

5.3.1 Dominant taxa and abundance in the Kitikmeot Sea

Taxa richness in the Kitikmeot Sea for this study identified 33 putative species where the majority (31 %) of the taxa belonged to the phylum Echinodermata (Figure 12). Mollusca was the second most speciose phylum that contributed to the taxa richness (12 %), whereas Cnidaria the third taxa rich phylum (9 %) in this study. Similarly, other photographic surveys conducted in the Arctic recorded also Echinodermata as the most taxon rich group (e.g. Piepenburg and Schmid 1997c; MacDonald *et al.,* 2010a), whereas Porifera was found to be the most taxon rich group in other studies (e.g. Mayer and Piepenburg 1996; Sswat *et al.,* 2015). Porifera was not even recorded on the images in this study, probably due to the low photographic resolution, but can regardless have been present on the images since some specimens were caught in the dredge at sampling locations. Some of the taxa classified as morphotypes or ‘unknown’ may have been Porifera, however, the confidence was not strong enough to identify specimens from the images. Even though the taxonomic resolution mostly stopped at order or class level from image analysis (Table 3), dredge collections confirm that many of these taxa are Arctic-boreal taxa widely distributed throughout the Arctic (Smirnov 1994; Sirenko 2001).

The number of taxa for the studies that have been compiled in Table 13, including the present one, is low compared to catches caught in trawl-based epifauna studies (Table 12). The likely reasons for low taxa richness can be due to methodological constraints related to image analysis, which was described in *3.2.2 Image collection, processing and analysis*. For this case study in the Kitikmeot Sea, the unknown taxa and morphotypes accounted for as much as 24% of the taxa inventory list. However, this is not the only study where organisms remained categorized as unknown and morphotypes, rather this is typical when it comes to identifying epibenthic invertebrates in photographic analyses (e.g. MacDonald *et al*., 2010a; Bergmann *et al.,* 2011; Taylor *et al*., 2016).

This study is the first that presents epibenthic abundance estimates from underwater imagery analysis in the poorly studied the Kitikmeot Sea in the CAA and comparisons from other studies in the same area are not available. Throughout the study area, the highest abundances were recorded at the sites with low flow current regimes (stations AP1 and AP2), whereas the transitional sites had the lowest abundance. Even if no studies are comparable to this work conducted in the Kitikmeot Sea, there was however one trawl-based station located in Dease Strait in vicinity of the stations that were taken close to Finlayson Islands in the present study. This trawl station had low biomass (0.03 – 3.42 g wet weight m^2) and low density (0.08 – 7.64 ind. per m^2) (Roy *et al*., 2014), much lower than the density in the present study (Table 2). Furthermore, the abundance ranges varied a lot within and among other studies in the Arctic (Table 13). Despite the large ranges overall, it is possible to see that deeper stations had a lower abundance range than the studies that were conducted at the shelves (Table 13).

On Arctic shelves including the Kitikmeot Sea, ophiuroids were mainly the dominating taxa in abundance and biomass (Table 13). Ophiuroids reached maximum abundances of 177.4 ind. per m^2 at station AP2 (low flow station), located in Bathurst Inlet, where the ophiuroids in the images were most likely the species *Ophiocten sericeum,* based on the trawl catches. The reasons for why these organisms attain such high densities are still poorly known, but it is suggested that low predation pressure can be an important factor determining the densities (Piepenburg 2000; Grebmeier *et al.,* 2006a). Fish and crabs that are known predators of ophiuroids (e.g. Divine *et al.,* 2017) were barely recorded on the images for this study and can be the possible explanation to the high abundances of brittle stars. High densities of ophiuroids is not a rare phenomenon and have also been observed by photographic- and trawl surveys in other places in the Arctic as well; including NEG (Mayer and Piepenburg 1996; Piepenburg and Schmid 1996a), Laptev Sea (Piepenburg and Schmid 1997c), Chukchi Sea (Ambrose *et al.*,

2001) and Barents Sea (Piepenburg and Schmid 1996b). In the Barents Sea, the species was shown to have pronounced patchiness with very high abundances at some locations. Piepenburg and Schmid (1996b) recorded up to 2,800 individuals of *Ophiocten sericeum* in one single image and the dominance decreased drastically at stations deeper than 150 m. This could not be verified in this study since only shallow stations were covered. In addition, the peak abundance was lower than in Barents Sea and Laptev Sea in Eurasian Arctic (Piepenburg and Schmid 1996b; Piepenburg and Schmid 1997c).

The low flow sites were the deepest stations in the study region (75 – 93 m) and consisted mostly of soft sediment, where 11 and 12 taxa were present at stations AP1 and AP2, respectively. In contrast to soft bottoms, the habitat heterogeneity increases the taxa richness (Buhl-Mortensen *et al.* 2012, this study).

Despite low taxon richness, abundance at these sites was comparatively high as noted above, although the Kitikmeot Sea is considered an oligotrophic area (C.J. Mundy, University of Manitoba, pers. comm.). The high densities of brittle stars, *Ophiocten sericeum*, in these slow current regime are, therefore, probably related to advection of organic particles. Another study conducted further east in the CAA also detected high biomasses in oligotrophic conditions and relate their findings to hydrographical features and combination of polynyas that continuously sustain the surrounding environments with food supply (Roy *et al.,* 2014). Similarly, Williams *et al*., (2017) discuss the theory of potential so-called “summer gardens” and “winter holes”, small areas in narrow passages where ice opens when tidally driven vertical mixing occurs (see Williams *et al*., 2017 for details), allowing higher than average primary production. If this is the case in the Kitikmeot Sea, it may explain why there were high abundances of brittle stars in the soft bottom sites of this study. In detail, how much these regions contribute to high biological activity still needs to be assessed.

Table 13: A summary of imagery sampling that has been conducted on Arctic shelves and in Arctic Basins. Information of how many taxa, sampling depth, range of station means, dominant taxa, study area are shown in this table.

No. of taxa	Depth (m)	Range of station means (No. of ind. per m^2)	Dominant taxa	Study area	Literature
33	17 - 93	4.6 – 208.7 (Mean density)	Low flow: Ophiuroidea (likely *Ophiocten sericeum*) High flow: Crinoidea	Kitimeot Sea, Canadian Arctic Archipelago	This study
28	80 – 360	Offshore: 1.6 – 18.7 Inshore: 3.2 – 90.2	Ophiuroidea, Decapoda (shrimps)	Kongsfjorden (Svalbard)	Bergmann *et al*., (2011)
141	50 – 450	1.4 – 40.0	*Ophiura sarsii, Gersemia rubiformis*	North of Svalbard	Sswat *et al.,* (2015)
6	80 – 360	32 – 524 (median abundance range) (Ophiuroidea only)	*Ophiocten sericeum, Ophiacantha bidentata, Ophiopholis aculeata, Ophiura sarsii, Ophioscolex glacialis, Ophiopleura borealis*	Barents Sea	Piepenburg and Schmid (1996b)
13	14 - 45	0.1 – 579.5	*Ophiocten sericeum, Ophiura sarsii, Myriotrocus rinckii, Similipecten greenlandicu)*	Laptev Sea	Piepenburg and Schmid (1997c)
15	28.9 – 212.5	0.2 – 256.6 (Echinodermata only)	*Ophiura sarsii, Ophiura maculata, Ophiopholis aculeata, Stegophiura nodosa, Echinarachnius parma*	Chukchi Sea	Ambrose *et al*., (2001)
91	190 – 2800	15 – 200	*Nothria conchylega,* (polychaete), *Polymastia* spp. (sponge)	Northeast Greenland	Mayer and Piepenburg (1996)
29	2341 – 2788	11.2 – 26.7	*Kolga hyalina, Mohnia* spp., *Bathycrinus carpenterii, Gersemia, fruticosa, Elpidia heckeri*	Fram Strait, HAUSGARTEN	Taylor *et al*., (2016)
67	817 - 3961	0.08 – 5.8	Holothuroidea, Cnidaria	Canadian Basin	MacDonald *et al*., (2010a)

5.3.2 Relating environmental parameters to epibenthic communities in the Kitikmeot Sea

This study is the first to describe epibenthic communities and to see if feeding types are related to the current velocities in this region. Differences were indeed obvious in both taxonomic and functional composition between sites with higher and lower current velocities. Throughout the study area, there were low salinities as a result of major river discharges to the region, which varied from 27.7 to 29.9. The fresh water coming from surrounding rivers creates a lighter layer on top and prevents nutrients from below to pass the strong pycnocline which results in a low rate of primary production (C.J. Mundy, Univ. of Manitoba, pers. comm), where small amounts reaches the seafloor. The tidal currents in the study area break up the strongly stratified layer on top in the water column and create mixing (Hannah *et al.,* 2009), which is thought to mediate production via upward transport of nutrients. The high current regime in narrow passages then advects the mixed organic particles further from its origin, where they can sink to the seafloor when currents slow down.

Even if there was a small sampling effort in the study area, it was still possible to see a weak pattern that epibenthic community communities were different and that the currents could explain the feeding strategies. Epibenthic invertebrates can be indicative of long-term average conditions in an environment (Pisareva *et al.,* 2015). Though strong tidal currents and tidal mixing vary on timescales of the tidal cycle (Hannah *et al.,* 2009), they form recurrent patterns on longer time scales. From a biological perspective, low tidal currents can attract surface deposit feeders, whereas high tidal currents will attract suspension feeder and hence structure the epibenthic community feeding composition in the study area. How epibenthic community structure varies over time is not possible to look at in this study since the photographic analysis were only conducted only represents a snap shot in time during late summer in Arctic in 2016.

5.3.2.1 Low flow site communities

The low flow sites, which were indicated by fine grained sediment, had low taxon richness and high dominance of ophiuroids with moderate contributions by tube-forming polychaetes. These were the functional dominants of surface deposit feeders at these locations. Several studies in the Arctic have suggested that there is a strong link between the current velocities and the feeding strategies, where the surface deposit feeders are dominant in low current regimes, whereas suspension feeders are highly dominant when high flow current regimes are prevailing (e.g. Feder *et al.,* 1994; Grebmeier *et al.,* 2006b; Pisareva *et al.,* 2015). Weak or no currents allow sinking organic particles to settle to the seafloor which provides essential conditions to sustain surface deposit feeders (Feder *et al.,* 1994; Grebmeier *et al.,* 2006b; Pisareva *et al.,* 2015) and it is probably why surface deposit feeders were the major representative group of the different feeding strategies in this study area. Environments with low current regime will be unfavorable for suspension feeders since water movement is insufficient to sustain taxa that obtain particles from the water column.

Similar observations have been made on a larger geographical scale in the central Chukchi Sea. Pacific water passes through the narrow Bering Strait with high current velocity and brings organic particles to the region that settles to seafloor when currents slows down in the open area further north (e.g. Grebmeier and Barry 1991; Grebmeier *et al*., 1995). Mainly surface deposit feeders were found in this region as well and are linked to the sinking particles that reaches the seafloor when currents slows down (Feder *et al.,* 1994; Grebmeier *et al.,* 2006b; Pisareva *et al.,* 2015), which coincides with the findings from this study.

Additionally, the low flow sites are the stations that were closest to the delta of the Hood River in Bathurst Inlet (Figure 3) compared to the other stations in the study. Terrigenous carbon export to marine environments by river discharge can provide a carbon subsidy to oligotrophic Arctic nearshore systems (Dunton *et al.,* 2006), hence increase the proportion of deposit feeders when particles reach areas of low current regimes. Whether the Hood River provides valuable organic material to the epibenthic communities located at the low flow sites in this study remains unknown, but could be studied by using trophic markers (e.g. Bell *et al.,* 2016).

5.3.2.2 Transitional site communities

The two stations in "transitional site" showed both a shift in dominance of taxa throughout the station transects on local scale, which was related to the shift in dominant sediment type, and as discussed sediment type can reflect what kind of feeding strategies are found in a habitat (Snelgrove and Butman 1995). Otherwise, these two sites were far apart with large differences between them, which makes it therefore difficult to see biological similarities between the transitional sites in the ordination. One station resembled more a station with to low current regimes (station UN4), whereas the other resembled more the stations with high currents (station TG), based on the feeding strategies (Figure 18).

Station Tinney Gate (TG) had one of the lowest salinity values in the study which was probably related to river discharge from the Burnside River in vicinity where the station transect was taken. Since there was a high sediment heterogeneity along the transect at this site, higher taxon richness was expected, but the low salinity could have limited taxa richness in TG. When salinities are very low, echinoderms for example, will struggle with osmoregulation (Hickman *et al.,* 2014), which makes such sites uninhabitable for this group. Additionally, the station had high turbidity and again, the Burnside River can also be a reason for the high turbidity, which continuously provides terrestrial input and freshwater to the environment.

5.3.2.3 High flow site communities

Sites with high current regime – as indicated by rocky substratum, had highest taxa richness, were characterized by crinoids, anemones, holothurians, and macroalgae, and functionally by suspension feeders. The high diversity can be linked to the sediment heterogeneity with differently sized rocks found on the high flow sites, where the rocky substratum allows settlement of sessile species that requires hard substrate to attach (Tissot *et al*., 2006).

In general, suspension feeders require an environment where there is a constant flow of organic particles (Gili and Coma 1998; Grebmeier and Barry 1991), which is the case in areas where there are strong currents in the water column (Blanchard and Feder 2014). Again, this linkage can be seen in Bering Strait and Barrow Canyon in the Chukchi Sea where high currents prevail along with suspension feeders (Feder *et al.,* 1994, Grebmeier *et al.,* 2006b, Pisareva *et al*., 2015).

Strong tidal mixing has been mapped in Dease Strait in vicinity of station TP and the stations close to Finlayson Island (Hannah *et al.,* 2009). The mixing that occurs in this region distributes organic particles throughout the entire water column and creates suitable feeding conditions for suspension feeders that require sustained flow of food particles. Additionally, in the presence of light at the shallowest stations with high current regime, (e.g. UN1) grazing organisms were also found since also primary producers such as macroalgae inhabited this station.

Interestingly, observations from a study conducted in the eastern CAA revealed that ophiuroids also occurred between pebbles and it was suggested that these areas were less exposed to currents and food particles were accumulating in-between (Marmen *et al*., 2017). This case was not possible to observe in this study and, in fact, very few representatives from the taxa Ophiuroidea were present at the stations where high current regimes were prevailing.

6 Conclusions and outlook

The present investigations of the two outflow shelves in the Arctic can be called a pioneer study. This study has created scientific baselines in two poorly studied and uncharted regions of the Arctic like the Norwegian historical explorers did in the same regions a century ago. This study is the first that quantitatively describes epibenthic communities by underwater imagery analysis in the Kitikmeot Sea in the CAA. Furthermore, this study is also one of the first that describes epibenthic communities and their relation to environmental parameters by abundance-based biological data in Northeast Greenland (NEG) by trawling. Both investigations confirmed epibenthic community variability within shelf regions in relationship to environmental gradients, but also demonstrated commonalities between shelf areas in terms of common and dominant taxa.

Both investigations provide a snap shot in time and space of the epibenthic invertebrates at the spatial scale of habitat types, but more comprehensive research on seasonal and interannual temporal and pan-Arctic scales is needed to predict changes in Arctic marine ecosystems before human footprints become too visible. A multi-methodological approach for studying Arctic epibenthic communities can be beneficial to avoid the obvious inherent methodological issues encountered in this study, and also to better understand the epibenthic communities by adding *in situ* observations together with catch of physical specimens. Improvement of taxonomical identification on underwater imagery analysis can be implemented if the photo of specimens are taken from different angles and even better, if the same specimens can be caught. In light of climate change and a great curiosity to the uncharted, it is hence even more important to monitor where Arctic and sub-Arctic biota meet as the Arctic Ocean temperature is increasing. Observations of possible changes in climate will be where West Spitzbergen current merges with cold water along the Greenland shelf break and slope. Furthermore, on the CAA side, a closer collaboration between marine geologists may help to interpret epibenthic communities better, a collaboration which was established in the NEG study. If future work by the TUNU Programme could conduct sampling even closer to the marine-terminating Soranerbræen in Bessel Fjord than this study did, it could be resolved if inner Bessel Fjord communities resemble other high Arctic fjords where suspension feeders were absent. For future studies in NEG with the TUNU Programme, I would suggest also a multivariate biomass-based analysis since colonial species were not taken into account in the abundance-based analysis.

I have experienced that it is difficult to present the actual reality, but the used depictions for these studies are simplifications to understand how the epibenthic communities functions. The acquired knowledge from these two studies conducted in the Arctic will help us build scenarios on how Arctic marine ecosystems may respond to climate changes and other human pressures. Habitat and associated epibenthic community heterogeneity documented on sub-regional to smaller scales across both study areas suggests that site specific environmental assessments must be conducted prior to human development in Arctic shelf areas.

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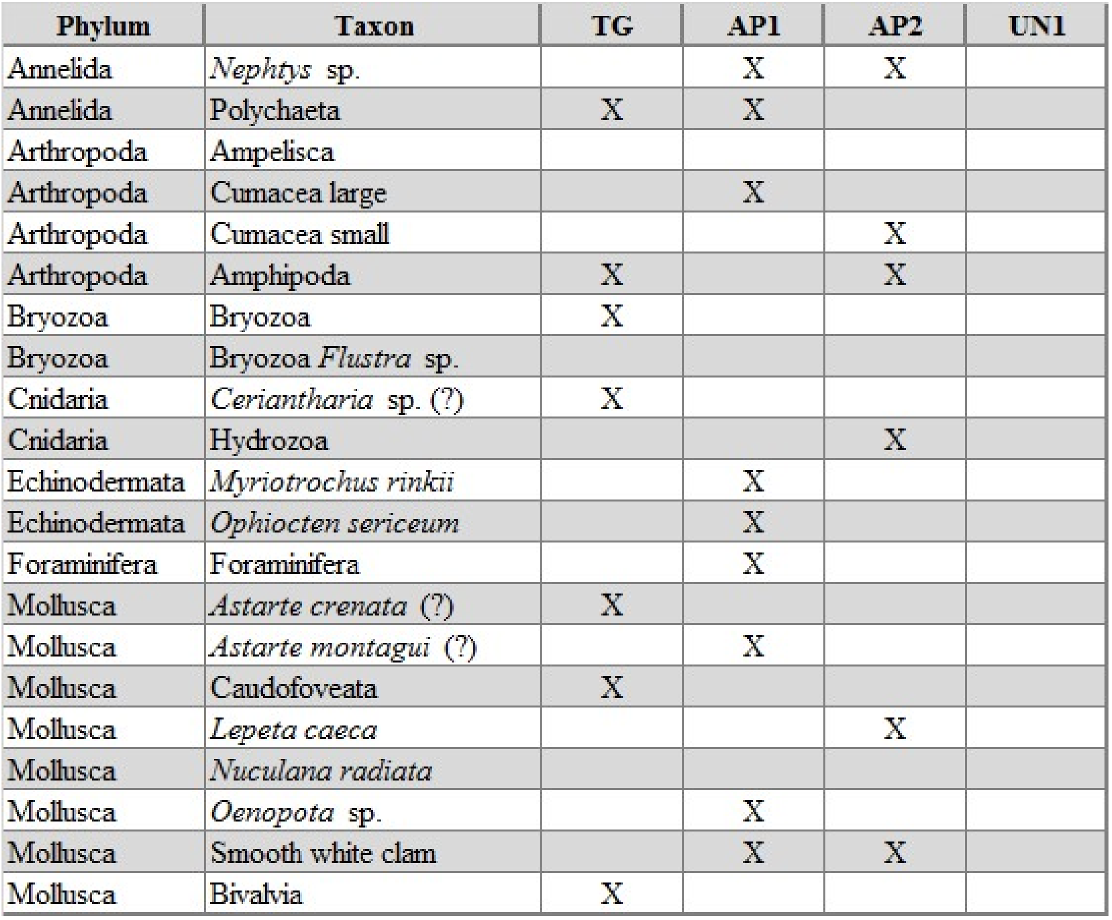
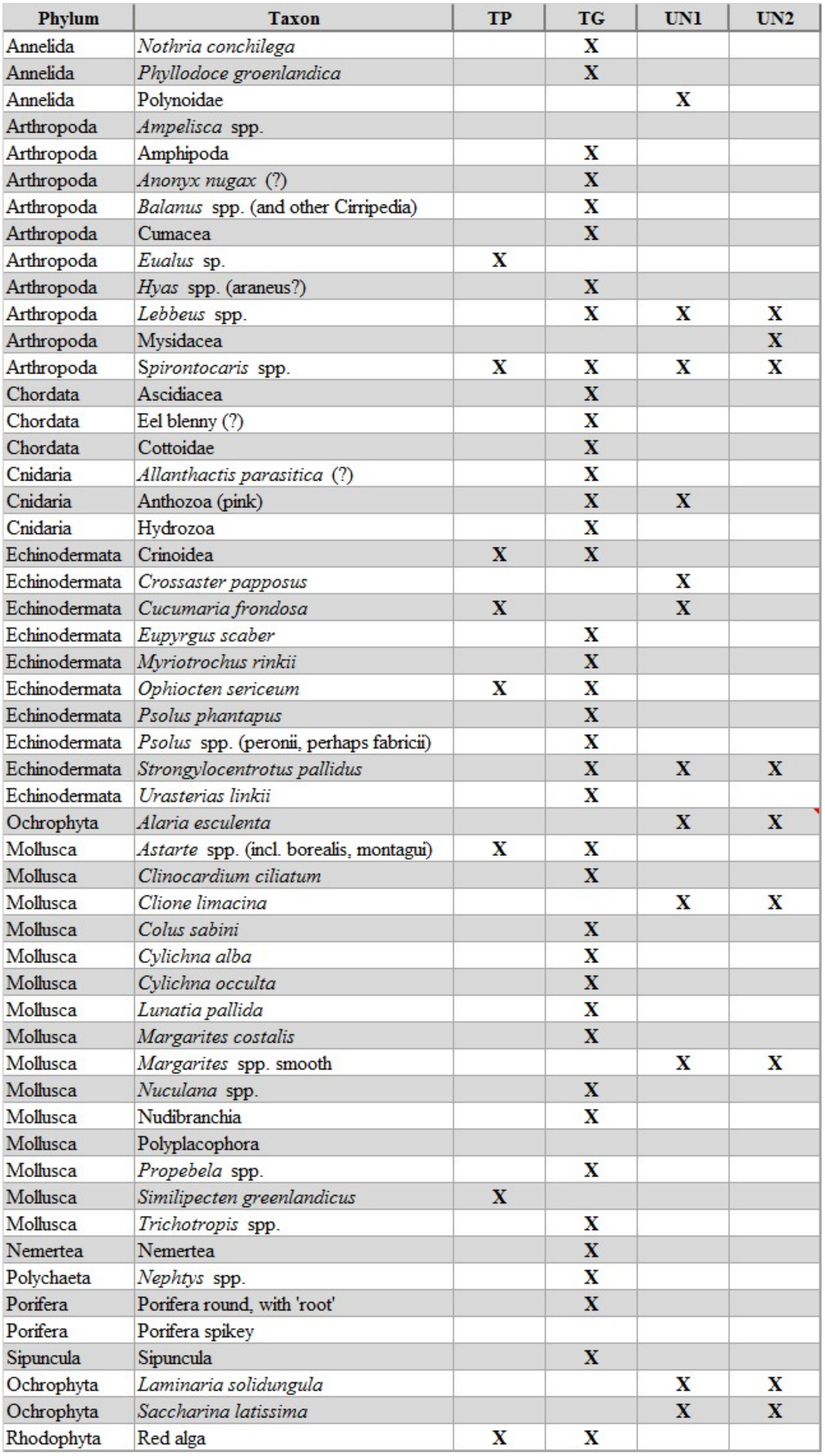
Appendix

Appendix Table 1: List of field-identified taxa that were present in van Veen Grab samples (Wilco, 0.1 m^2) in the Kitikmeot Sea in August 2016. Specimens were used as support material for better identification of epibenthos in underwater imagery analysis. At some stations, the grab failed to collect sediment and specimens due to rocky seafloor.

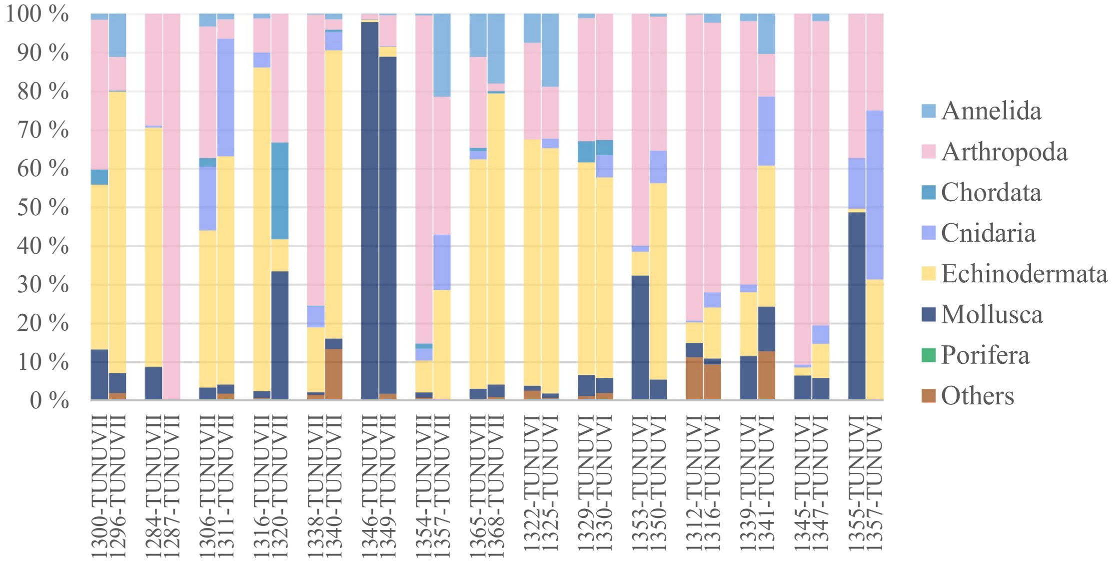


Phylum	Taxon	TG	AP1	AP2	UN1
Annelida	*Nephtys* sp.		X	X	
Annelida	Polychaeta	X	X		
Arthropoda	Ampelisca				
Arthropoda	Cumacea large		X		
Arthropoda	Cumacea small			X	
Arthropoda	Amphipoda	X		X	
Bryozoa	Bryozoa	X			
Bryozoa	Bryozoa *Flustra* sp.				
Cnidaria	*Ceriantharia* sp. (?)	X			
Cnidaria	Hydrozoa			X	
Echinodermata	*Myriotrochus rinkii*		X		
Echinodermata	*Ophiocten sericeum*		X		
Foraminifera	Foraminifera		X		
Mollusca	*Astarte crenata* (?)	X			
Mollusca	*Astarte montagui* (?)		X		
Mollusca	Caudofoveata	X			
Mollusca	*Lepeta caeca*			X	
Mollusca	*Nuculana radiata*				
Mollusca	*Oenopota* sp.		X		
Mollusca	Smooth white clam		X	X	
Mollusca	Bivalvia	X			

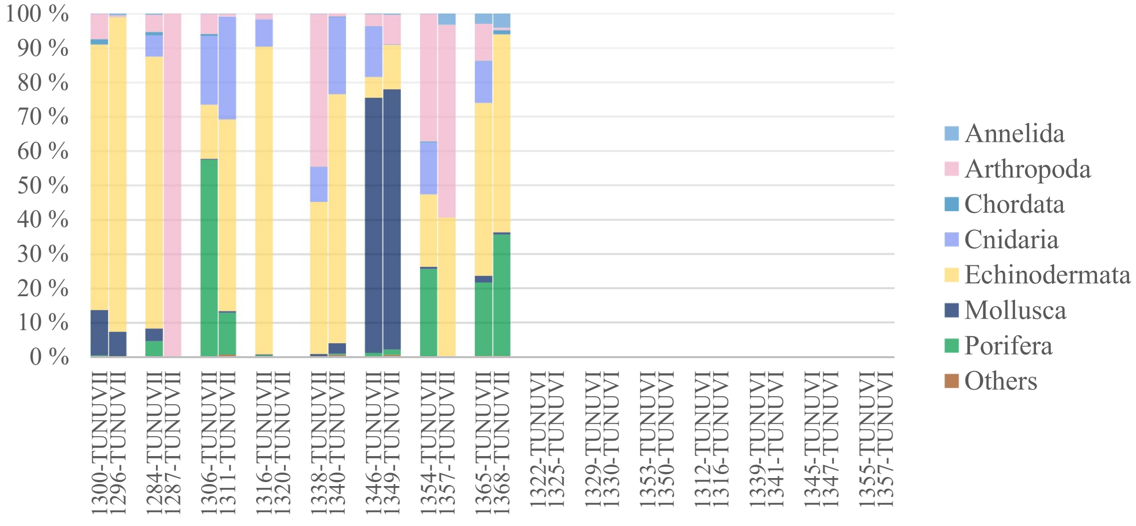
Appendix Table 2: List of field-identified taxa caught in dredge in the Kitikmeot Sea in August in 2016. Specimens were used as support material for better identification of epibenthos in underwater imagery analysis. At some stations the dredge failed to collect specimens.



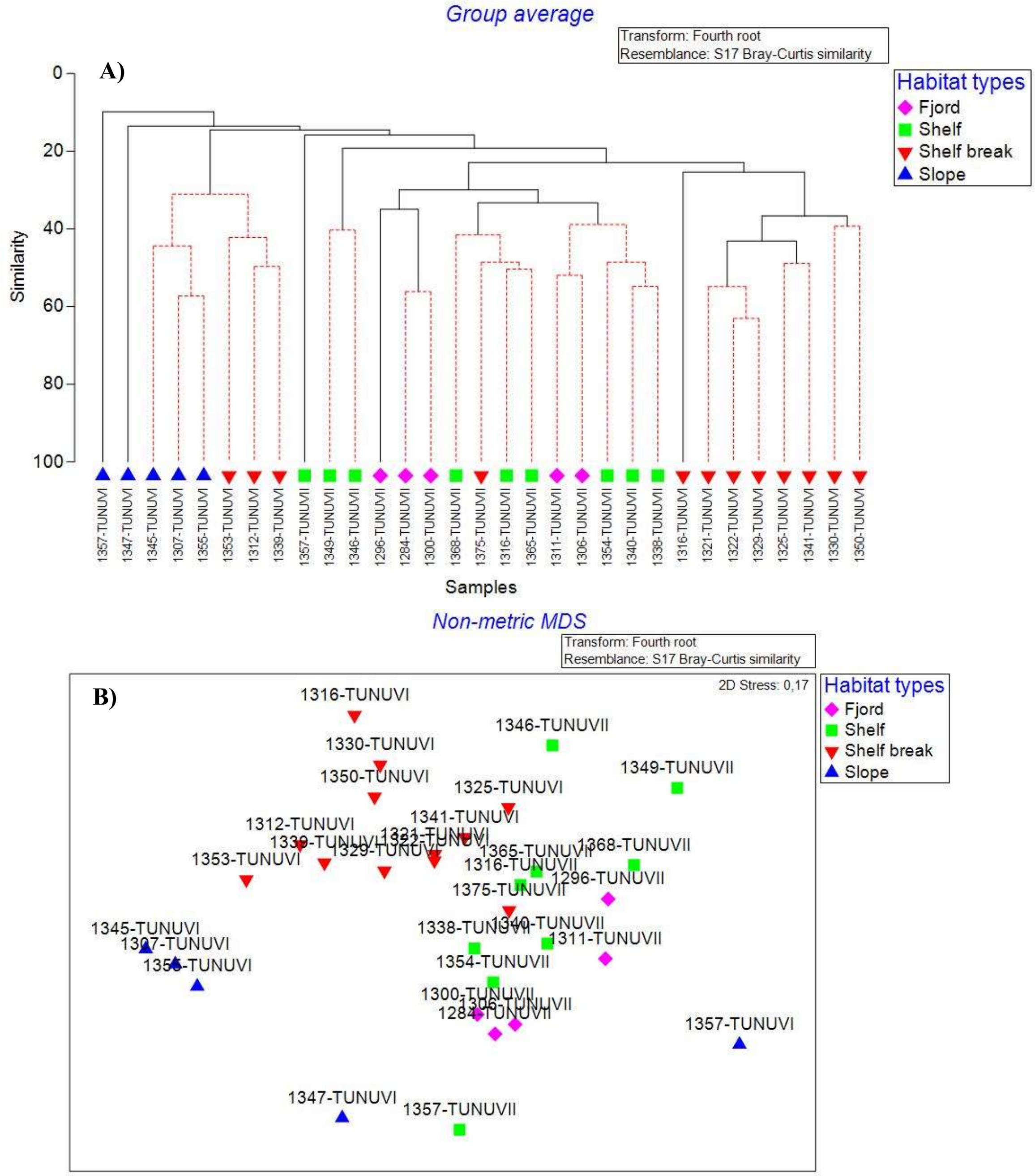
Phylum	Taxon	TP	TG	UN1	UN2
Annelida	*Nothria conchilega*		X		
Annelida	*Phyllodoce groenlandica*		X		
Annelida	Polynoidae			X	
Arthropoda	*Ampelisca* spp.				
Arthropoda	Amphipoda		X		
Arthropoda	*Anonyx nugax* (?)		X		
Arthropoda	*Balanus* spp. (and other Cirripedia)		X		
Arthropoda	Cumacea		X		
Arthropoda	*Eualus* sp.	X			
Arthropoda	*Hyas* spp. (araneus?)		X		
Arthropoda	*Lebbeus* spp.		X	X	X
Arthropoda	Mysidacea				X
Arthropoda	*Spirontocaris* spp.	X	X	X	X
Chordata	Ascidiacea		X		
Chordata	Eel blenny (?)		X		
Chordata	Cottoidae		X		
Cnidaria	*Allanthactis parasitica* (?)		X		
Cnidaria	Anthozoa (pink)		X	X	
Cnidaria	Hydrozoa		X		
Echinodermata	Crinoidea	X	X		
Echinodermata	*Crossaster papposus*			X	
Echinodermata	*Cucumaria frondosa*	X		X	
Echinodermata	*Eupyrgus scaber*		X		
Echinodermata	*Myriotrochus rinkii*		X		
Echinodermata	*Ophiocten sericeum*	X	X		
Echinodermata	*Psolus phantapus*		X		
Echinodermata	*Psolus* spp. (peronii, perhaps fabricii)		X		
Echinodermata	*Strongylocentrotus pallidus*		X	X	X
Echinodermata	*Urasterias linkii*		X		
Ochrophyta	*Alaria esculenta*			X	X
Mollusca	*Astarte* spp. (incl. borealis, montagui)	X	X		
Mollusca	*Clinocardium ciliatum*		X		
Mollusca	*Clione limacina*			X	X
Mollusca	*Colus sabini*		X		
Mollusca	*Cylichna alba*		X		
Mollusca	*Cylichna occulta*		X		
Mollusca	*Lunatia pallida*		X		
Mollusca	*Margarites costalis*		X		
Mollusca	*Margarites* spp. smooth			X	X
Mollusca	*Nuculana* spp.		X		
Mollusca	Nudibranchia		X		
Mollusca	Polyplacophora				
Mollusca	*Propebela* spp.		X		
Mollusca	*Similipecten greenlandicus*	X			
Mollusca	*Trichotropis* spp.		X		
Nemertea	Nemertea		X		
Polychaeta	*Nephtys* spp.		X		
Porifera	Porifera round, with 'root'		X		
Porifera	Porifera spikey				
Sipuncula	Sipuncula		X		
Ochrophyta	*Laminaria solidungula*			X	X
Ochrophyta	*Saccharina latissima*			X	X
Rhodophyta	Red alga	X	X		



Appendix Figure 1: The relative composition of numbers of individuals caught for two gear types that were deployed during TUNU-VI (2015) and TUNU-VII (2017) expeditions to Northeast Greenland (NEG) for collecting epibenthic invertebrates. Two bars were put closely together represent one location each where the left represents the Campelen trawl hauls and the right bar represents Agassiz trawl hauls. This graph is not showing stations from 1307-TUNUVI, 1321-TUNUVI and 1375-TUNUVII since only one gear was deployed at these locations. Colonial taxa are excluded.



Appendix Figure 2: The relative composition of epibenthic invertebrate weight caught with two gear types that were deployed during TUNU-VII (2017) expedition to Northeast Greenland (NEG) for collecting epibenthic invertebrates. Two bars were put closely together represent one location each where the left represents the Campelen trawl hauls and the right bar represents Agassiz trawl hauls. This graph is not showing stations from 1307-TUNUVI, 1321-TUNUVI and 1375-TUNUVII since only one gear was deployed at these locations. Colonial taxa are excluded.



Appendix Figure 3: Station similarities of Northeast Greenland (NEG) trawl where the stations grouped by habitat type with relative abundance-based data of epibenthic invertebrates from two gear types Campelen 1800 shrimp trawl and Agassiz trawl that was deployed during TUNU-VI (2015) and TUNU-VII (2017) expeditions to Northeast Greenland (NEG). **A)** Station clusters obtained from the hierarchical cluster analysis (HCA) with fourth-root transformed relative abundance. Red dotted lines indicate that the clusters are not statistically significant different (SIMPROF test α = 0.05). **B)** nMDS plot of the relative abundance-based data.

Appendix Table 3: Differences between epifaunal communities in different habitats shown in pairwise tests computed with ANOSIM from a Bray-Curtis resemblance matrix on epifaunal abundance data from the TUNU expeditions to Northeast Greenland in 2015 and 2017. Table depicts also which habitat types were tested, if there was a strong separation (responding to a R value close to 1), the significance level, possible permutations and number observed.

Global Test	Groups (Habitat type)	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >= Observed
	Slope, Shelf break	0.754	0.8	120	120	1
Sample statistic (R): 0.781	Slope, Fjord	1	10	10	10	1
Significance level of sample statistic: 0.1%	Slope, Shelf	1	1.8	56	56	1
Number of permutations: 999 (Random sample from 147026880)	Shelf break, Fjord	0.845	0.8	120	120	1
Number of permuted statistics greater than or equal to R: 0	Shelf break, Shelf	0.646	0.4	792	792	3
	Fjord, Shelf	0.713	1.8	56	56	1

Appendix Table 4: Differences between epifaunal communities in different habitats shown in pairwise tests computed with ANOSIM from a Bray-Curtis resemblance matrix and Gower similarity coefficient (S15) on square-root transformed epifaunal abundance from the Kitikmeot Sea in August 2016. Table depicts also which habitat types were tested, if it suggests a strong separation, the significance level. possible permutations, actual permutations and number observed. Table depicts also which habitat types were tested, if there was a strong separation (responding to a R value close to 1), the significance level, possible permutations and number observed.

Gower S15						
Global Test		**R**	**Significance**	**Possible**	**Actual**	**Number >=**
Sample statistic (R): ***0,2***	**Groups (sites)**	**Statistic**	**Level %**	**Permutations**	**Permutations**	**Observed**
Significance level of sample statistic: ***16.2%***	High flow, Transition site	0.083	50	10	10	5
Number of permutations: 105 (All possible permutations)	High flow, Low flow	0.333	30	10	10	3
Number of permuted statistics greater than or equal to R: 17	Transition site, Low flow	0.75	33.3	3	3	1
Bray-Curtis						
Global Test		**R**	**Significance**	**Possible**	**Actual**	**Number >=**
Sample statistic (R): ***0,6***	**Groups (sites)**	**Statistic**	**Level %**	**Permutations**	**Permutations**	**Observed**
Significance level of sample statistic: ***5.7%***	High flow, Transition site	0.083	40	10	10	4
Number of permutations: 105 (All possible permutations)	High flow, Low flow	1	10	10	10	1
Number of permuted statistics greater than or equal to R: 6	Transition site, Low flow	1	33.3	3	3	1