
*Abundance and vertical distributions of zooplankton
along the east-west gradient of phytoplankton biomass
in the North Water (Arctic Ocean)*



Mysis oculata imaged by the Lightframe Onsite Keyspecies Investigation (LOKI) system in Baffin Bay, 2013.

Kevin Gonthier

Director : Louis Fortier

Supervisor : Moritz Schmid

Takuvik, Université Laval, Québec, QC, Canada G1V 0A6

Québec-Océan, Université Laval, Québec, QC, Canada G1V 0A6

Département de Biologie, Université Laval, Québec, QC, Canada G1V 0A6

Abstract

In the Arctic Ocean copepods transfer energy produced by autotrophs to higher trophic levels. Net tows have long been used as the main zooplankton sampling tool but can hardly indicate the abundance and distribution of these animals on a fine-scale level. The LOKI (Lightframe On-sight Keyspecies Investigation) is an *in-situ* optical underwater imaging device capable of recording the vertical distribution of zooplankton at a scale of ~30-60 cm. Using this device, the fine-scale distribution of the key herbivorous copepods *Calanus glacialis* and *C. hyperboreus* as well as that of the omnivore *Metridia longa* was analyzed. It was investigated how the fine-scale vertical distribution of copepods was coupled to fluorescence of microalgae during the phytoplankton bloom and how that pattern differed between eastern and western North Water Polynya. Eastern and western NOW showed substantial differences in the fluorescence of microalgae which seemed to influence the fine-scale copepod distribution. Whereas copepod abundance and fluorescence seemed almost vertically separated on the Canadian side of the polynya, the abundance of the same taxa showed a strong vertical coupling with fluorescence on the Greenland side. The results suggest a strong influence of physical parameters in the NOW (e.g. temperature and upwelling), likely governed by the West Greenland Current and Baffin Island Current, on microalgae and hence fine-scale zooplankton distribution.

Keywords: Arctic Ocean, North Water Polynya, Copepods, Optical underwater imaging, Automatic Species identification, (Lightframe On-sight Keyspecies Investigation) LOKI, fine-scale vertical distribution

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Introduction

■ *The Arctic environment:*

The Arctic is an environment where strong seasonality occurs due to changes in incoming solar radiations (Nuttall 2005). Variations are notably observed in weather conditions, light levels and sea ice variations (i.e. extent and thickness). During the polar night, food resources as well as primary production levels are limited (Seebens et al. 2009, Pawlowska et al. 2011). This limitation is mainly due to the absence of light in the water column and the presence and thickness of the sea ice cover (Wassmann 2011). During spring, sea ice starts to melt, leading to more irradiance in the water column. Autotrophic processes, mainly generated by ice algae and phytoplankton throughout the rest of the summer, then take place and allow for the commencement of primary production (Slagstad et al. 2011). The very foundation of the Arctic food web relies on this primary production as it sustains the second level of the foodweb, the zooplankton (Vidussi et al. 2004, Leu et al. 2011).

Important features in the Arctic are polynyas. Polynyas are regions of open water that are surrounded by ice and distributed throughout the polar seas (Hannah et al. 2008). There, primary producers have access to light early in the season (Tremblay et al. 2002). As such, polynyas can support more life than other places in the Arctic and are considered highly productive ecosystems (Ringuette et al. 2002). Out of the polynyas found in the Canadian Arctic Archipelago, the North Water Polynya (NOW) (~75 to 79° N, ~71 to 78°W) between Ellesmere Island and Greenland in northern Baffin Bay is important for the study presented here since the study area is partially located within the NOW (Figure 2). Latent heat (i.e. air and oceanic currents) and sensible heat (i.e. upwellings along the Greenland coast) mechanisms contribute to keep this area free of ice and rich in nutrients, ensuring a strong primary production (Melling et al. 2001, Lee et al. 2003, Tremblay et al. 2006).

■ Zooplankton and phytoplankton:

Phytoplankton distribution is mainly controlled by the nutrients available and light conditions in the euphotic zone (Slagstad et al. 2011). Grazing pressure by zooplankton usually only has limited impact (Barton 2014) on the phytoplankton population. Nevertheless, zooplankton transfer carbon to higher trophic levels and can be herbivore, omnivore or even predatory. Zooplankton are then predated on by forage fish (e.g. the Arctic cod; Darnis et al. 2014), seabirds and others. This intermediate trophic level is prey for top predators (e.g. the polar bear; Bromaghin et al. 2015, Darnis et al. 2012, Heide-Jørgensen et al. 2012) (Figure 1). The coupling of primary and secondary production is an important part of the oceanic carbon cycle (Tremblay et al. 2006), and therefore a key component in the complex structures ruling the Arctic marine ecosystem.

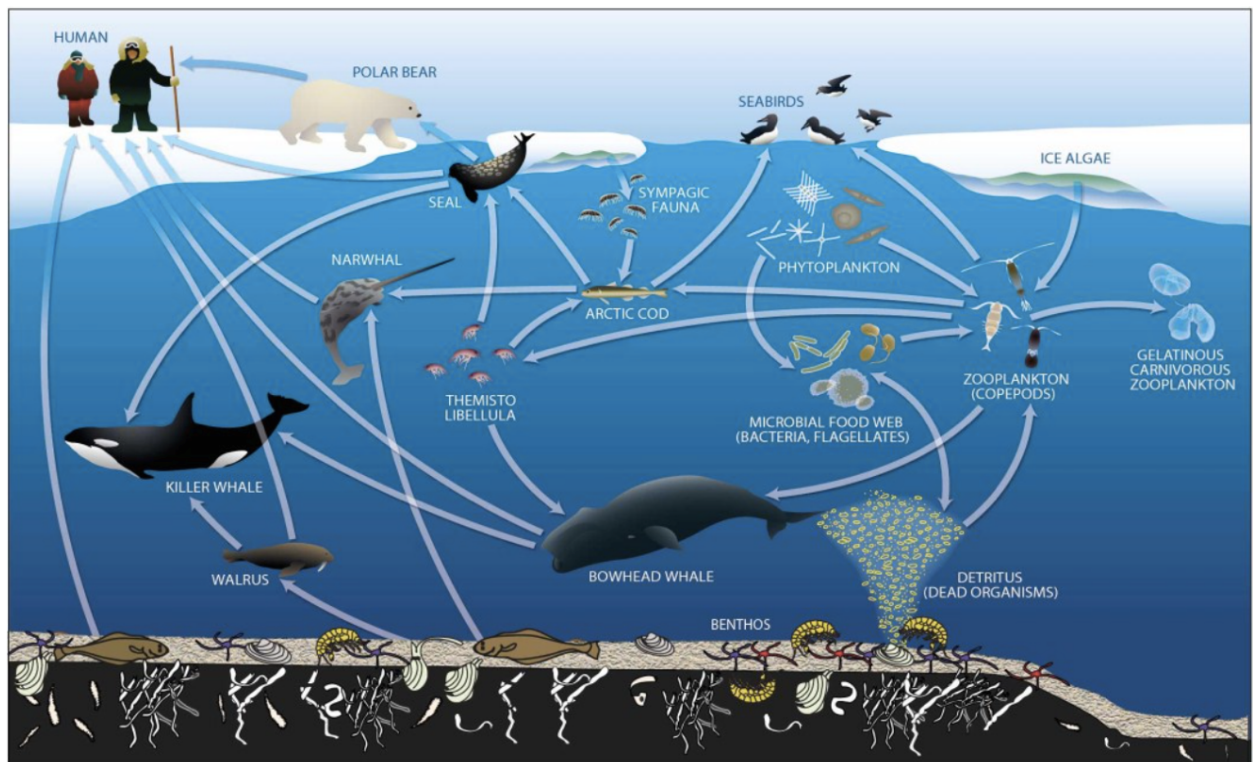


Figure 1: Arctic foodweb (Darnis et al. 2012).

An important part of the progression of phytoplankton blooms are subsurface chlorophyll maximum layers (SCM), prevalent in the Arctic ocean (Brown et al. 2015). They are the result

of inorganic nitrate depletion at the surface and progressive deprivation of light at depth (Martin et al. 2012) leading to the sinking of phytoplankton cells. SCMs in Northern Baffin Bay contribute substantially to the carbon flow in the Arctic foodweb (Martin et al. 2010).

Zooplankton are heterotrophic animals found all over the world. The most abundant taxa among the Arctic species belong to the group of copepods as they compose about 80% of the zooplankton biomass of these regions (Conover 1988, Ringuette et al. 2002). Their average size range varies between 0.2 and 20 millimeters (Kimmel et al. 2010). Since they possess weak swimming capabilities, their mobility is mostly dependent on oceanic currents (Miller 2004). Major constituents of their algal diet include diatoms, dinoflagellates and coccolithophores (Miller 2004). Cannibalistic behavior among zooplankton has also been observed (Daan et al. 1988) including predation on other copepod's eggs and larvae (Mauchline 1998). The life cycle of copepods is complex and comprises several development stages (Mauchline 1998). In order to survive the challenges imposed by the Arctic environmental conditions, they have developed unique ontogenetic traits (i.e. seasonal and diel vertical migrations, metabolic adjustments and feeding ecology; Conover and Huntley 1991, Hirche 1998, Auel and Hagen 2005, Connelly et al. 2016). Many species migrate to deeper parts of the ocean (several hundreds of meters) (Ashjian et al. 2003, Rabindranath et al. 2011, Darnis et al. 2014) and enter a state of diapause, triggered by external signals, to facilitate overwintering through the polar night (Conover and Huntley 1991, Stasio 2004). Diel migration patterns also exist. Most often this migration means that copepods are at depth during day time and travel back to the surface at night (variations exist), a pattern that seems to be mostly a result of predator avoidance and the need to feed (Fortier et al. 2001 Berge et al. 2009, Steele and Henderson 1998). In fact, zooplankton abundance is mostly driven by predation pressure (Nicolle et al. 2011). The intensity of predation pressure correlates with the seasonal presence of predators (Nicolle et al. 2011).

Both the vertical and horizontal dimensions of the ocean are ruled by the ongoing heterogeneous physical conditions and their dynamics (Sullivan et al. 2010). The distribution of plankton is shaped by these biological and physical processes on all spatial scales (Marine Zooplankton Colloquium 1 1989). The current understanding is that physical processes are

most important on a large scale whereas biological processes are most important on a micro scale (Daly and Smith 1993). Patchy and dense aggregations of plankton reflect the heterogeneity of the surrounding environment (McManus et al. 2005, Sullivan et al. 2010). These patches can be present as thin layers, which are dense aggregations with a vertical extent of centimeters to a few meters but can have a horizontal extent which can reach kilometers (Greer et al. 2013). Important ecological roles and functions are fulfilled by these thin layers as they effect trophic interactions (e.g. predator-prey) of organisms within and near those layers (Sullivan et al. 2010, Greer et al. 2013).

The North Water is characterized by two main currents. The eastern region of the polynya is ruled by the West Greenland Current (WGC) which originates from the Atlantic Ocean and thus carries warm and salty waters (Müchow et al. 2015). The WGC circulates at depth along the Greenland Coast and has been known to generate upwellings, potentially leading to increased productivity (Melling et al. 2001, Slagstad et al. 2011). The Baffin Island Current (BIC) comes from the Arctic Ocean, bringing forth cold and freshwater on the surface layer of the western region (Bâcle et al. 2002, Müchow et al. 2015). Ringuette et al. 2002 observed that phytoplankton growth starts in the eastern sector of the NOW and then progresses westward, with its highest biomass on the Greenland side (Figure 2).

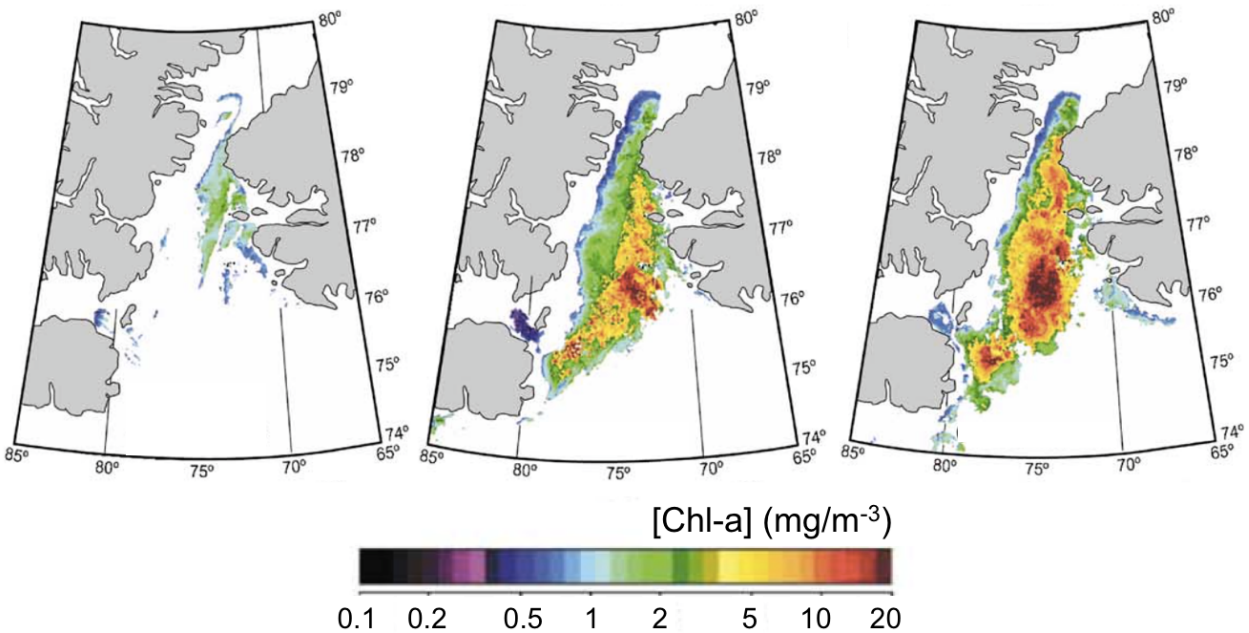


Figure 2: Distribution of Chl *a* in the North Water (Adapted from Ringuette et al. 2002).

■ **Dominant Arctic copepods:**

This study focuses on three important Arctic copepod taxa.

Calanus hyperboreus:



Figure 3: *Calanus hyperboreus* female

Calanus hyperboreus (Fig. 3) is abundant in the Arctic Ocean and one of the key grazers (Hirche 1991). It has a multi-year life cycle (Hirche 2013). This animal possesses the biggest lipid reserves amongst the three dominant Arctic copepods and relies on them to survive the overwintering/diapause phase and for spawning (Nørregaard et al. 2013, Davies et al. 2015). During winter, females lay their non-buoyant eggs which will then float back to the surface right under the sea ice. As the eggs are rising, the larvae begin their maturation and utilize the phytoplankton bloom to sustain themselves (Conover and Huntley 1991).

Calanus glacialis:



Figure 4: *Calanus glacialis* female

The main areas of distribution for *Calanus glacialis* (Fig. 4) are the Arctic Shelf seas (Søreide et al. 2010). The length of its life cycle can reach three years (Leu et al. 2011). Its diet mainly consists of phytoplankton cells (Søreide et al. 2010), but when this resource is lacking, *C. glacialis* can acquire energy from alternative sources such as ice algae and protozooplankton (Levinsen et al. 2000). During its diapause, the animal relies on its lipid reserves which also provide the energy for the eggs to develop (Zarubin et al. 2014). Its reproduction is synchronised with the beginning of the ice melt to allow a greater time period for larvae to feed on the microscopic algae (Conover and Huntley 1991).

Metridia longa:

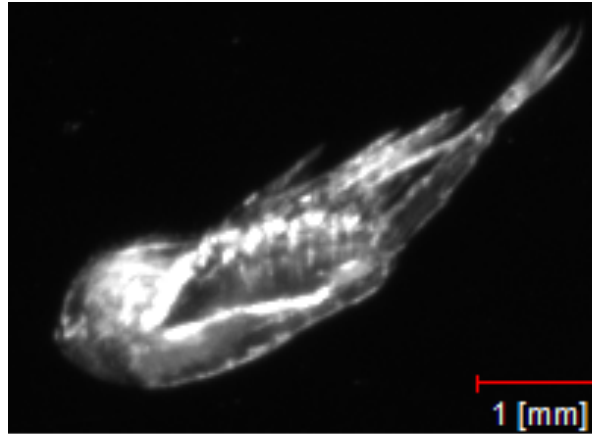


Figure 5: *Metridia longa* female

Metridia longa (Fig. 5) is a deep-water species (Veistheim et al. 2013) whose habitat spreads from the Chukchi Sea and the northern Atlantic all up to the Arctic (Hirche 1991). Its life expectancy is about a full-year (Grønvik and Hopkins 1984). This animal is omnivorous as it feeds on other copepods eggs, larvae and phytoplankton (Ringuette et al. 2002). *M. longa* overwinter as active adults (Grønvik and Hopkins 1984) and females start spawning in May (Båmstedt and Tande 1988).

■ **Optical underwater imaging and automatic identification of images:**

Zooplankton net tows are being used as the main zooplankton sampling tool. A downside of zooplankton nets is that they integrate zooplankton over large parts of the water column and can therefore not describe vertical zooplankton distribution on a fine-scale level (Schulz et al. 2009). *In-situ* optical imaging systems offer high precision measurements of the vertical distribution of zooplankton. Environmental data can be recorded with optical imaging systems as well which makes it possible to relate the fine-scale vertical distribution of zooplankton directly with the environment the zooplankter lives in.

This study utilizes the LOKI (Lightframe On-sight Keyspecies Investigation), an underwater zooplankton camera. It is capable of recording the vertical distribution of zooplankton at a scale of ~10-50 cm. One of its unique features is a built-in zooplankton concentration net, with

a diameter of 60 cm, which leads to a more representative sampling of the water column as opposed to a simple through-flow chamber (Schulz et al. 2010). Optical underwater imaging systems gather many thousands or even millions of images. Manual identification of all of these images would be too time consuming. Therefore, automatic zooplankton identification models are used to identify zooplankton taxa on images based on a set of image parameters (e.g. greyness level of image pixels). These models first have to be “trained” on images that were manually identified. A computer program can then learn the association between image parameters and associated zooplankton taxa.

The vast majority of past investigations on the distribution and abundance of zooplankton and the underlying environmental driving forces were conducted using nets. Nets stratify the water column only roughly. A better understanding of the distribution pattern of zooplankton can be gained by utilizing sampling systems that can resolve the water column at a better vertical resolution. Here we investigate the fine-scale vertical distribution of key zooplankton taxa (at the stage level) during a phytoplankton bloom using an optical imaging system which is capable to resolve the water column at 0.1-0.5 m intervals.

■ **Goals and hypotheses:**

This study aims at describing key zooplankton taxa and their fine-vertical distribution under bloom and post-bloom conditions in relation with the east-west gradient of phytoplankton in the North Water Polynya. The extent to which the eastern area of the NOW is more productive than its western area and the potential impact of this gradient on the zooplankton community was investigated.

Hypotheses:

1. The zooplankton abundance (Individuals per m³) of the three target species (*Calanus hyperboreus*, *Calanus glacialis* and *Metridia longa*) is highest in the eastern section of the North Water.
2. The vertical distribution of these three species is coupled with the subsurface chlorophyll maximum layer.

Materials and methods

■ Study area:

The study region is Northern Baffin Bay (~ 76 to 80° N, ~ 68 to 77° W), between Ellesmere Island and Greenland. This area comprises several stations that were sampled using LOKI during the ArcticNet 2013 mission. The stations can be roughly divided into two sections based on their latitude (southern and northern stations) and represent a transect from North to South on which a phytoplankton bloom was also observed. ArcticNet 2013 took place from July 26th to September 18th on board of the CCGS *Amundsen* research vessel. LOKI was deployed at stations 101, 115, 117 and 126 (Fig. 6 and Table 1).

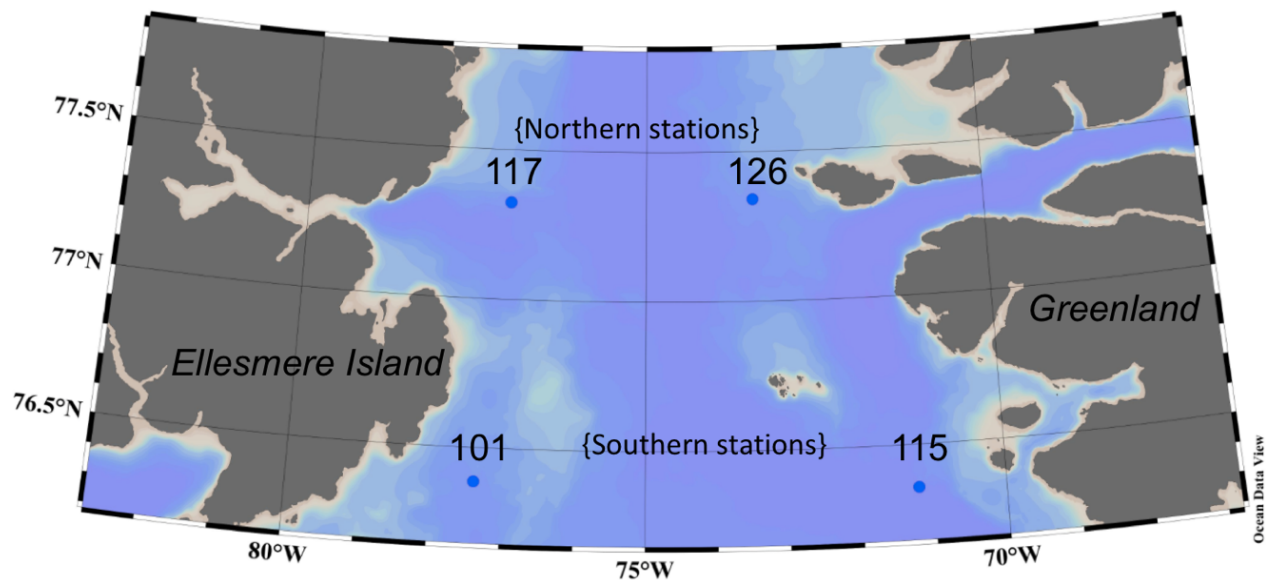


Fig. 6: Oceanographic stations sampled during ArcticNet 2013.

Table 1: Dates and coordinates of LOKI and ArcticNet CTD deployments.

Station	Date	Latitude °N	Longitude °W	Bottom depth (m)
101	2013-08-15	76° 23.26	77°22.74'	347
115	2013-08-18	76°20.477'	71°11.756'	654
117	2013-08-28	77°19.29'	77°0.42'	449
126	2013-08-27	77°20.65'	73°25.64'	324

■ **LOKI deployment:**

The LOKI was deployed as part of a 5-Net Vertical Sampler (5NVS; Fig. 7). The 5NVS is a sampling setup on which up to 5 different nets can be deployed (Schmid 2016). During LOKI deployment, integrated sensors (Fig. 8) record environmental data. These data include oxygen saturation and concentration, temperature, salinity, pressure and fluorescence. These parameters were recorded every second and associated with the corresponding pictures by means of a timestamp.



Figure 7: LOKI attached to a 5-Net Vertical Sampler.
Photo credit: Jessy Barrette



Figure 8: LOKI camera with deployment frame and other components. From Isitec GmbH.

■ **Data preparation:**

Relevant images from the ascent of LOKI through the water column were imported into LOKI browser software. In a first step, this program was used to associate the images taken with the environmental data. In a second step, LOKI browser was used to measure image parameters for each picture taken. In the process, the outline of the zooplankter in the image is detected and parameters such as surface area, circularity, convexity and homogeneity measured (see Schmid et al. 2016 for more details). During LOKI deployments, it can happen that zooplankton specimen go slower through the camera than anticipated, resulting in multiple images taken of the same specimen. These double images would bias abundance and biomass estimates and consequently have to be filtered out. Therefore, the ZOOMIE (Zooplankton Multiple Image Exclusion) process was applied (see Schmid et al. 2015 for more details) and used to detect and exclude double images in all oceanographic station which were analyzed.

The final selection of images was then quality controlled by using ADOBE Bridge and Photoshop. In the process, smears on the camera lens or light reflections on the borders of the images were deleted. GUIDOS (Graphical User Interface for the Description of image Objects and their Shapes) software toolbox was used (see Schmid et al. 2016 for details) to assess spatial features of each image through mesh analysis (i.e. fragmentation, Jaeger 2000) and Morphological Spatial Pattern Analysis (MSPA) (i.e. geometry and connectivity patterns, Vogt 2014)

■ **Automatic identification model:**

The dataset consisting of the parameters of each image analyzed by LOKI browser (e.g. greyness of image pixel) and GUIDOS toolbox (e.g. fragmentation) were then utilized for automatic species identification. Using Salford Systems Data Mining Suite, the model developed by Schmid et al. (2016) was applied and a species identification for each image obtained. The model was previously trained on 36260 images using Salford Systems implementation of the Random Forests algorithm. The model works very well for the copepods selected in this study (86% overall accuracy and specificity for 114 zooplankton classes; Schmid et al. 2016).

■ **Analyses and statistical methods:**

The zooplankton distribution along the studied transect was analyzed by plotting both zooplankton abundance and fluorescence (used as a chl *a* proxy) against depth. All analyses were carried out using scripts written in the R language.

Results

■ Hydrography overview:

In the eastern sector of the North Water, both southern station 115 and northern station 126 showed a steep thermocline ranging from 10 meters depth down to 40 meters. Thermoclines on the Canadian side occurred between 10 meters and down to a hundred meters for station 101. It also ranged from 40 meters to 60 meters in the North transect. Temperatures of surface waters on the southern transect were above 3°C whereas the northern transect was colder with 2°C at station 126 and just below 0°C at station 117 (Figs. 9-10).

Surface waters from the northern transect showed similar oxygen concentration along the East-West axis (i.e. 8 ml/L) at a depth of 25 meters. In the South, the most oxygenated layer of station 115 was found at 25 meters (9 ml/L), while station 101 peaked at 8 ml/L, 10 meters deeper (Figs. 9 -10).

Salinity profiles in the western and eastern sectors of the polynya showed values inferior to 32 psu on the surface level. Salinity at stations 101 and 115 was characterized by a sharp increase in the first 25 meters, reaching more than 34 psu at 300 meters depth. On the northern transect, salinity profiles were similar, but with a slightly more gradual increase at station 126 than at its southern counterpart (Figs. 9-10).

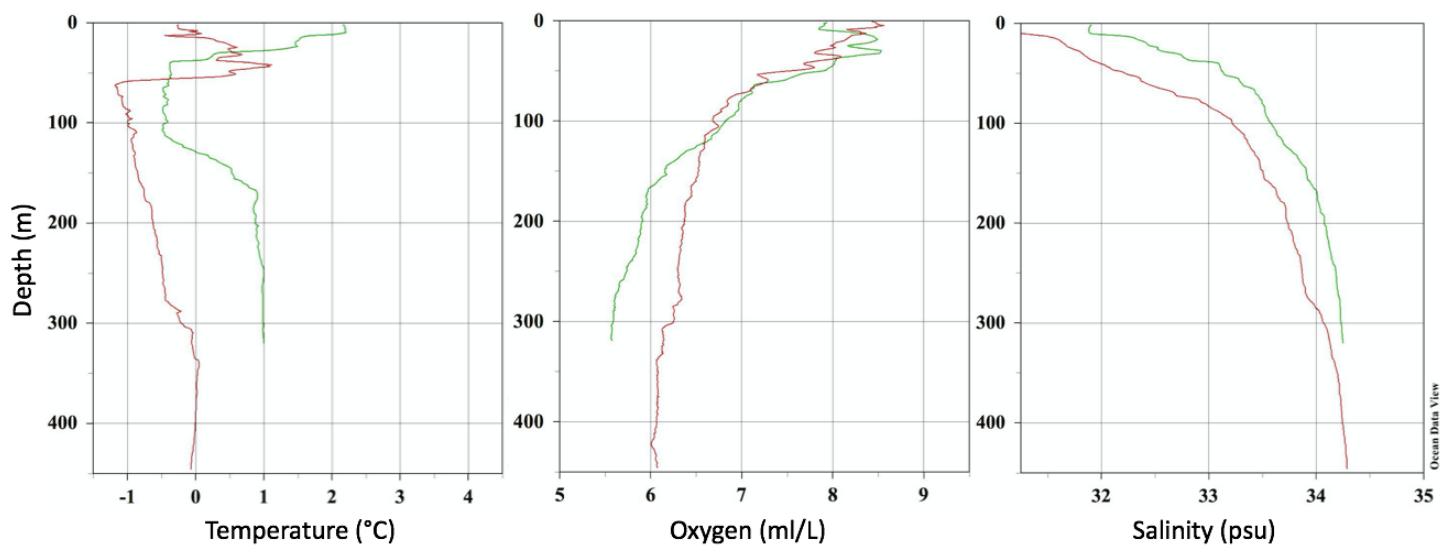


Figure 9: Vertical profiles of temperature, oxygen concentration and salinity in North transect. A red curve indicates station 117 (west sector) and a green curve indicates station 126 (east sector).

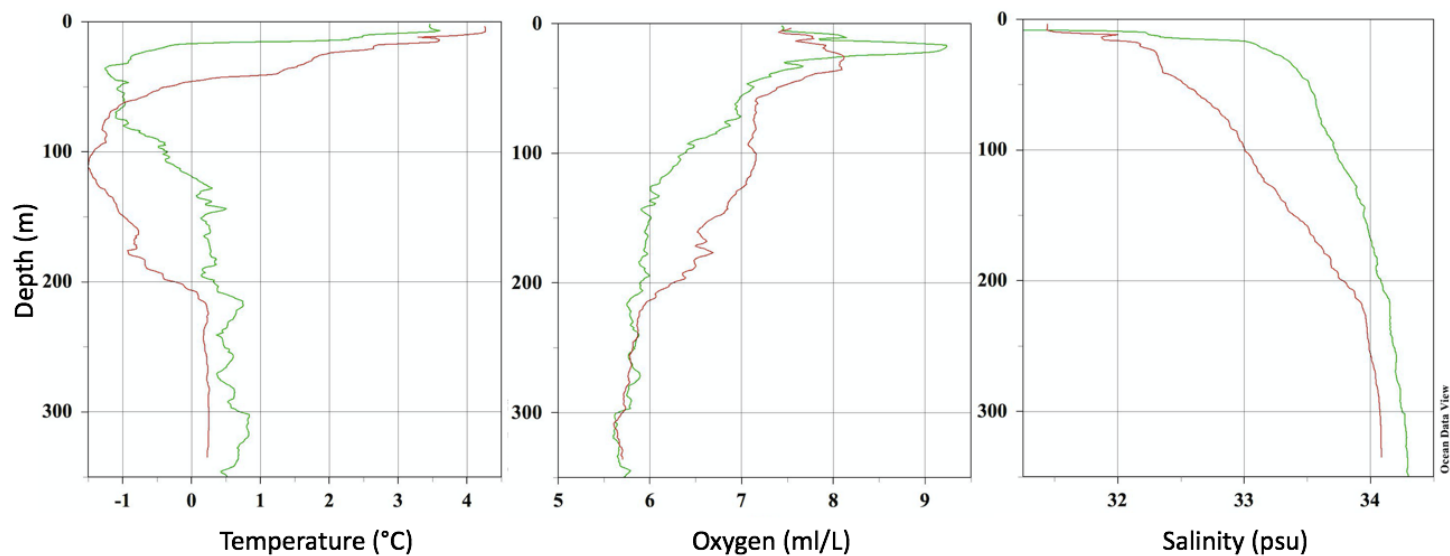


Figure 10: Vertical profiles of temperature, oxygen concentration and salinity in South transect. A red curve indicates station 101 (west sector) and a green curve indicates station 115 (east sector).

■ **Abundance and stage composition:**

Northern Baffin Bay was mainly dominated by *Calanus hyperboreus* in terms of total abundance (24385 inds m⁻²). Abundance of this taxa ranged from 4899 inds m⁻² at station 117 to 5365 inds m⁻² at station 126. Abundance of *M. longa* at station 101 (13949 inds m⁻²) was similar to its herbivore counterpart *C. hyperboreus* (14122 inds m⁻²). Station 117 showed *M. longa* abundance of 1507 inds m⁻² which increased to 2787 inds m⁻² near the Greenland Coast at station 126. *M. longa* and *C. hyperboreus* females were always more abundant than their male counterparts. Total abundance of *C. glacialis* (14062 inds m⁻²) was the lowest of the three species and ranged from 1450 inds m⁻² at station 117 to 2324 inds m⁻² at station 126. Its stage composition was characterized by the absence of males. Apart from mature stages, stage C4 was dominant for *C. hyperboreus*, C1 showed prevalence for *M. longa* and C5 was the most abundant for *C. glacialis*. The station with the highest zooplankton abundance in the study region was 101 (41348 inds m⁻²) although station 117 showed the lowest (8011 inds m⁻²) (Tab. 2).

Table 2: Comparison of copepod abundances for each stage on the East-West axis of the North Water Polynya.

Species	Stage	Abundance (inds m ⁻²)			
		South		North	
	Sector Station	West 101	East 115	West 117	East 126
<i>Calanus glacialis</i>	C1	3088	-	4	39
	C4	1645	-	343	665
	C5	5234	-	1036	1489
	C6F	322	-	67	131
<i>Calanus hyperboreus</i>	C3	1634	-	163	279
	C4	10656	-	3526	3922
	C5	1574	-	870	683
	C6F	219	-	336	477
	C6M	39	-	4	4
<i>Calanus glacialis</i> C2 / <i>C. hyperboreus</i> C1	x	350	-	x	25
<i>Calanus glacialis</i> C3 / <i>C. hyperboreus</i> C2	x	2638	-	156	449
<i>Metridia longa</i>	C1	5673	-	32	184
	C2	2122	-	11	74
	C3	1103	-	35	113
	C4	1952	-	219	541
	C5	378	-	78	71
	C6F	2359	-	785	1358
	C6M	361	-	347	446
Total		41348	-	8011	10950

- = not analyzed yet, x = not present

■ Vertical distributions:

In the eastern sector of the northern transect, profiles of *C. glacialis* C5, *C. hyperboreus* C4 and *M. longa* C6F showed abundance peaks overlapping vertically with fluorescence peaks (Fig. 12). The same taxa showed deeper distributions and no vertical overlap with phytoplankton in the western sector (Fig. 11). On the southern transect, only fluorescence data is ready so far for the eastern station 115. Western station 101 showed a similar pattern to western station 117 further North, but abundances were substantially higher with no vertical overlap between zooplankton abundance peak and fluorescence peak.

Fluorescence serves as a proxy for phytoplankton growth. Intensities of fluorescence along the Greenland coast ranged between 5 and 6 mg/m³ (Figs. 12, 14). Fluorescence peaks occurred at around 40 meters depth. On the western side of the Polynya, highest fluorescence was 2 mg/m³ at station 117 (Fig. 11).

Station 126 was characterized by the highest peaks of copepod abundance for *C. glacialis* C5 (40 inds/m³), *C. hyperboreus* C4 (140 inds/m³) and *M. longa* C6F (90 inds/m³). Vertical distributions at station 117 were similar for all three taxa (Fig. 11). All species were absent from the surface level at station 101 through which *C. glacialis* C5, *C. hyperboreus* C4 and *M. longa* C6F showed highest abundances between 150 and 250 meters (Fig. 13).

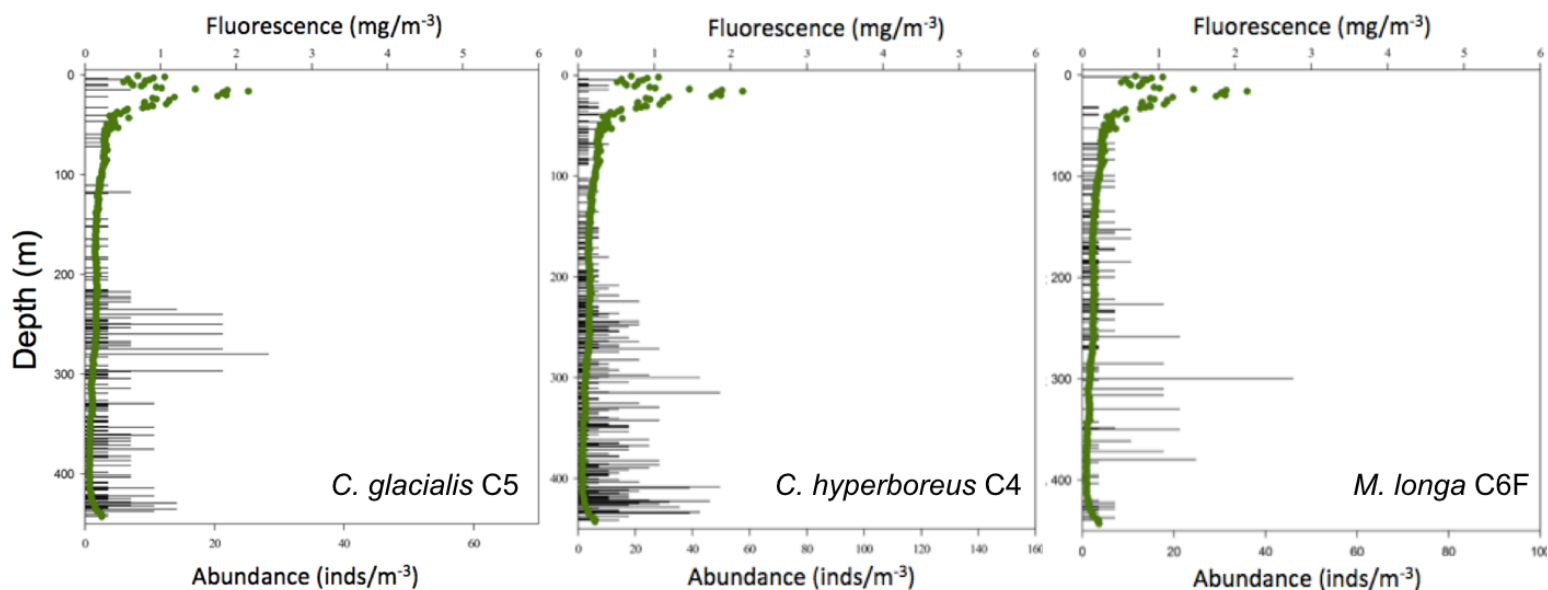


Figure 11: Vertical distributions of zooplankton taxa (abundance, inds/m⁻³) and vertical profile of fluorescence (mg/m⁻³) for station 117 (North-West in the study region). Species identification shown inside panels.

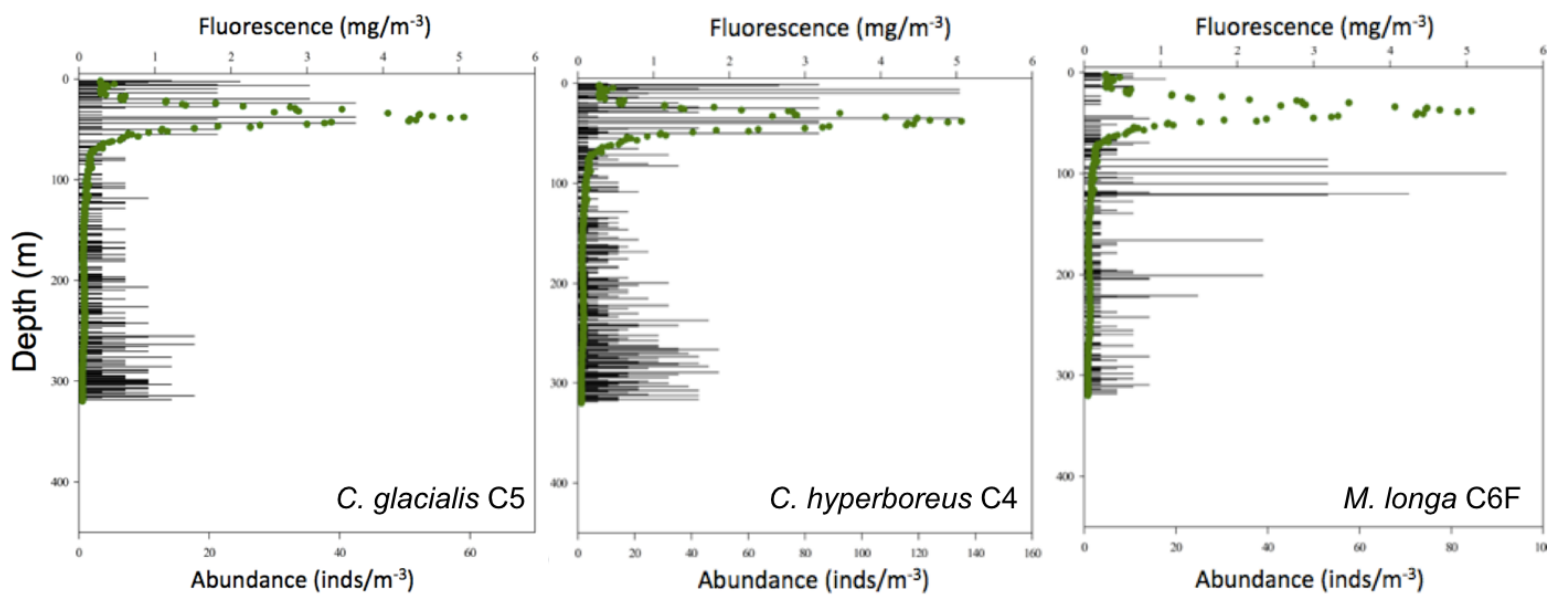


Figure 12: Vertical distributions of zooplankton taxa (abundance, inds/m⁻³) and vertical profile of fluorescence (mg/m⁻³) for station 126 (North-East in the study region). Species identification shown inside panels.

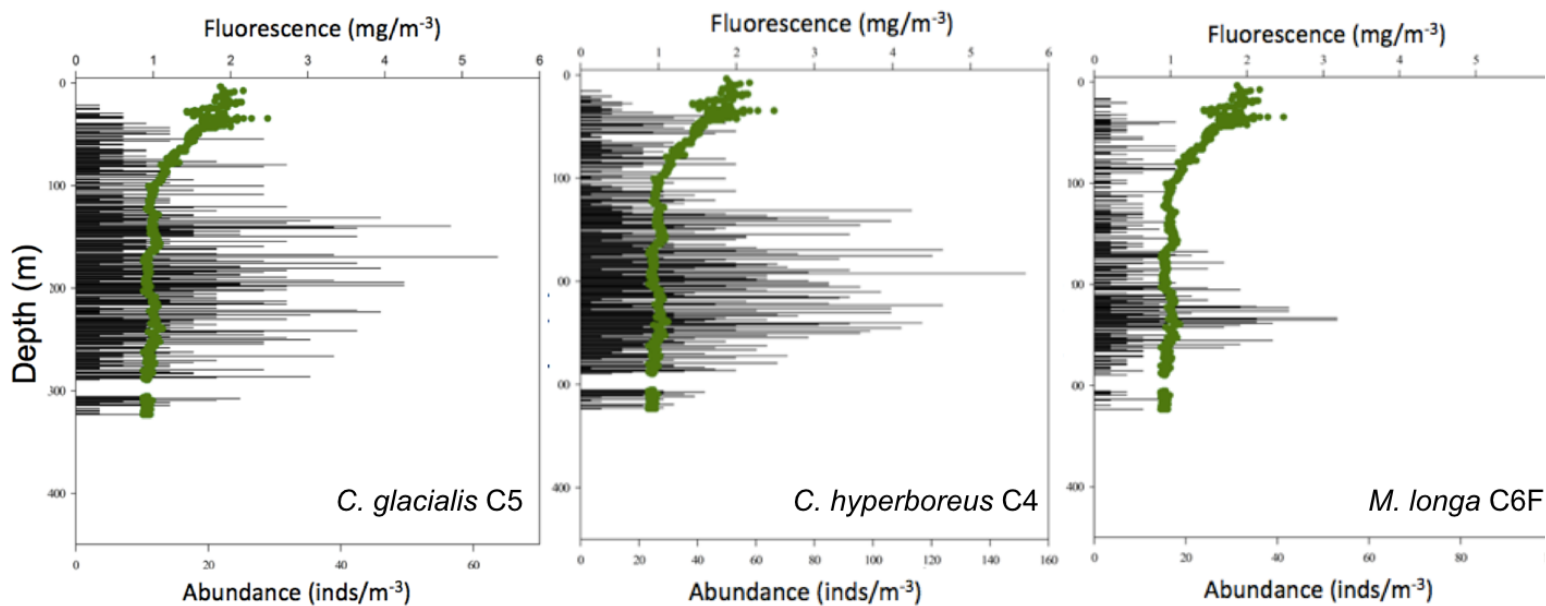


Figure 13: Vertical distributions of zooplankton taxa (abundance, inds/m⁻³) and vertical profile of fluorescence (mg/m⁻³) for station 101 (South-West in the study region). Species identification shown inside panels.

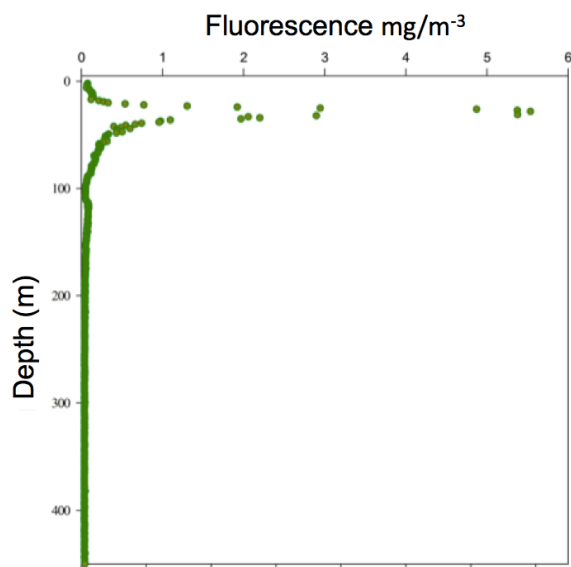


Figure 14: Vertical profile of fluorescence (mg/m⁻³) for station 115 (South-East in the study region).

Discussion

The main objective of this study was to investigate how the vertical distributions of key Arctic copepods overlapped with those of phytoplankton in August, at three stations in the North Water, and to compare the eastern sector of the NOW with the western.

Surface waters circulating through the eastern sector of the polynya were characterized by high temperatures relatively to the western sector. Previous studies have shown similar variation of hydrographical parameters between said sectors of the North Water (Bâcle et al. 2002, Ingram et al. 2002, Mûchow et al. 2015). These authors suggested such observations might be induced by the two main currents of the region; the West Greenland Current (WGC) and the Baffin Island Current (BIC). The WGC transports heat at depth (Melling 2002) from the Atlantic along the Greenland Coast, whereas the Canadian side's environment is influenced by cold waters from the Arctic Ocean forming the BIC (Mei et al. 2002, Mûchow et al. 2015). Variations between the characteristics of the two water masses are reflected by different types of phytoplankton roaming these areas as well as fluctuating phytoplankton biomass (Klein et al. 2002, Lovejoy et al. 2002). The gradient in phytoplankton biomass in the west compared to the east reported by other studies (Klein et al. 2002, Mei et al. 2002, Tremblay et al. 2002) was clearly shown. Elevated phytoplankton biomass in the eastern part (stations 126 and 115), as compared to stations 101 and 117, could be explained by an influence from the WGC, which is known to stimulate upwelling conditions, therefore having more nutrients available for phytoplankton (Melling et al. 2001, Tremblay et al. 2002) leading to increased zooplankton abundances to a plentiful food source.

Using fluorescence as a proxy for phytoplankton growth we identified similarities in the distributions of phytoplankton and the later stages of *C. glacialis* and *C. hyperboreus* copepods (C4 and C5 respectively) at station 126, where a considerable fraction of these animals were present in the upper 100 m. Our results corroborate what has been demonstrated in other studies; herbivore copepods heavily rely on their distributions overlapping with phytoplankton to sustain themselves in bloom conditions (i.e. in our context, fluorescence concentrations exceeding 5 mg/m³) (e.g. Conover and Huntley 1991, Miller 2004). In short, our observations outlined a strong tendency towards the coupling of primary and secondary production in the western sector of the

North Water. High abundances of *Calanus* sp. copepods near the surface may therefore be linked to the observed, optimal conditions for phytoplankton growth (Seebens et al. 2009, Søreide et al. 2010). However, copepods in shallower waters may be at increased risk of predation from visual predators such as fish (Mauchline 1998, Nicolle et al. 2011).

Nonetheless, considerable proportions of *C. glacialis* C4 and *C. hyperboreus* C5 copepods were also found in much deeper water at all stations. There were little similarities in the distributions of copepods and phytoplankton at stations 101 and 117. Indeed, copepod abundance and phytoplankton biomass seemed almost vertically separated on the Canadian side (i.e. stations 117-101) of the polynya. We assume this sector of the polynya was in post-bloom conditions for two reasons; the advancement of the season and the decreased phytoplankton biomass probably caused by nutrient depletion, leading to the sinking of organic carbon production processes (Martin et al. 2010 and Martin et al. 2012). Thus, decoupling of copepods from microalgae biomass was detected in the western sector of the North Water.

The annual routines of larger *Calanus* sp. copepods are well known; older stages especially are shown to perform seasonal migrations, moving upwards in the water in spring to feed notably on ice algae and phytoplankton, possibly reproduce and build fat stores over spring and summer, before later migrating downwards at depth to overwinter (Ashjian et al. 2003, Hirche 1997, Rabindranath et al. 2011, Stasio 2004). Our data suggest that most of the older *Calanus* sp. individuals in the western sector of our study area had already begun or finished their downward migrations after intense summer feeding. Madsen et al. 2001 published similar results in which they described how *C. glacialis* and *C. hyperboreus* were absent from the upper 50 m in Disko Bay (western Greenland), hinting at preparations for overwintering. They also suggested that ontogenetic migrations were performed by adults in order to better respond to food availability, thus increasing their odds of survival. At all stations older stages of *Metridia longa* were on average found deeper in the water column than older stages of *Calanus* sp., suggesting strong predator avoidance behavior, as proposed by other studies (Veistheim et al. 2013, Darnis et al. 2014). This could be because they are more omnivorous and experience a wider range of food sources such as detritus for sustenance in deep waters (Ringuette et al. 2002, Miller 2004). Previous studies have suggested that *M. longa* individuals do not overwinter, remaining active feeders year-

round, and therefore require smaller lipid sacs (Grønvik and Hopkins 1984). Catherine et al. 2004 found similar results and suggested that these animals are capable of relative omnivory, allowing them to adapt to the high seasonality of the Arctic environment. This roughly translates to copepods selecting alternative food sources (e.g. protists, and faecal pellets) when phytoplankton shortage occurs, thus proving insufficient abundance to sustain their populations (Atkinson 1996, Catherine et al. 2004).

The resolution obtained with the LOKI has proved insufficient to discern *C. glacialis* C2 from *C. hyperboreus* C1 and *C. glacialis* C3 from *C. hyperboreus* C2 and therefore these taxa were pooled into two groups (Schmid et al. 2016). This leads currently to difficulties when interpreting the observed pattern of these mixed groups. Further technological advancements are required to image all stages of these copepods. Once all LOKI images from southeastern station 115 are analyzed we will complement our observations and will see how this station fits into the picture described here.

Acknowledgements

I would like to extend my sincerest thanks to Prof. Louis Fortier, Moritz Schmid and Jordan Grigor for their contributions to this project (e.g. acquisition of data, providing the tools for analysis, advice and reviews). Cyril Aubry provided important training in species identification.

This study was funded by the Canada Foundation for Innovation (CFI) (no. CFI224324) and ArcticNet, a Network of Centres of Excellence of Canada (no. 12000). This is a joint contribution to Québec-Océan at Université Laval, ArcticNet, and the Canada Research Chair on the response of marine Arctic ecosystems to climate warming.

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