Grazing Indices of Zooplankton on Phytoplankton in the San Juan Channel in 2016

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Abstract

Plankton are a major component in the marine ecosystem being the base of the marine food web. This study tries to study the relationship in the San Juan Channel of zooplanktons top-down control on phytoplankton as well as examining how different water properties effect the plankton abundances. North station showed a strong incidence of grazing having a large pheaopigment concentration ranging from 0.24 μg/L at the surface to 0.19 μg/L at 50 m depth. This was followed by a high concentration of solitary phytoplankton around 30.51%.

Introduction

Plankton are an essential component to the marine ecosystem. There abundance and composition are major indicators of the oceans health as well as the animals that reside in it. Plankton are described as organisms that cannot swim against a current (Lalli 1993). These organisms are the base of the food web; thus predatory marine animals (i.e. fish, birds, marine mammals) rely heavily on the plankton community for energy (Calbet 2008).

Phytoplankton are the primary producers, thus using photosynthesis for energy. Phytoplankton contain many different genus and can be found in most bodies of water (Amburst 2009). Chained phytoplankton are cells that grow as a group, forming a chain-like structure used as a protective mechanism (Amburst 2009). Many chained phytoplankton contain spines repelling predation as well as keeping a natural buoyancy to stay in the euphotic zone (Van Donk 2011). In the San Juan Archipelago, where this study occurred, temperate zone diatoms are the most common phytoplankton. Here we divided phytoplankton into two major types: chained, with spines (i.e. *Chaetoceros*) and solitarty without spines (i.e. *Coscinodiscus*). Gifford et al., (1981) found significantly lower grazing rates by Calanoid copepods on the same species of diatom with spines, versus on cells grown without spines. Solitary cells, conversely, often lack spines and are easier for copepods to handle, thus unlike chained cells with spines, solitary phytoplankton are more easily consumed by predators.

As plankton are influenced by water current there are many properties that influence their distribution. In San Juan Channel, zooplankton have been found to be strongly related to flood tides, as the tide would transport the zooplankton as well as their food into the channel increasing their abundance (Zamon, 2002; Sigley 2012). Phytoplankton are known to be controlled by density gradients (Calbet 2015), and in San Juan Channel, water that is more stratified has been found to contain a higher concentration of phytoplankton (Tian 2016).

Zooplankton are mainly herbivorous consuming phytoplankton though carnivory is also common, with nauplii as their major food source. Zooplankton are a major food source for higher trophic level organisms (Laundry 1979). In late fall and winter when food is low, zooplankton go into a diapause phase where feeding stops. This overwintering phase, similar to hibernation, allows zooplankton to reduce their metabolism allowing them to survive long periods without food (Hirche 1996). This phase is brought on by certain conditions such as the length of the photoperiod and temporal cues (Watson 1971). In fall, the low abundance of phytoplankton is typically followed by diapausal copepods.

Grazing is the interaction between these two types of plankton. Grazing is a top-down control zooplankton on phytoplankton. Grazing, a process, is difficult to determine in the field as there are currently no straightforward methods that measure grazing rates directly. Also there are many other oceanic properties that control plankton abundance making it difficult to differentiate between grazing and/or another controlling factor.

In order to approximate grazing in this study, two indices were used. Because zooplankton selectively graze on solitary phytoplankton without long spines, and have difficulties consuming spined and longer chained phytoplankton, the relative abundance of these two phytoplankton groups can be an index favoring herbivory.

Another indicator of grazing is a high phaeopigment concentration. Phaeopigment is the degradation product of chlorophyll that can be found in the fecal material of zooplankton, due to the consumption of chlorophyll containing organisms such as phytoplankton (Head 1996).

The objectives of this study are to 1) compare the phytoplankton community with the zooplankton community over fall of 2016 in the San Juan Channel and to identify patterns and assess the interaction between the two types of plankton, focusing on grazing. 2) Determine whether the zooplankton or phytoplankton communities are affected by different oceanic properties (e.g. water column structure and tidal influences).

Methods

Data were collected along the San Juan Channel in the R/V Centennial. Station North was located at the northern tip of Shaw Island (48º35.00'N, 123º02.50'), South station was located near Cattle Pass (122º56.60' W) (Figure 1). Data was collected on October 4th, 11th and 28th as well as November 1st and 9th in 2016. Samples were then analyzed at Friday Harbor Labs. Samples were not collected on a weekly basis due to weather complications.

<u>Plankton sampling</u>

Two different nets were used to catch plankton samples at both North and South station. Zooplankton net tows using 153 µm mesh and 0.7 m diameter, were lowered 10m above the seafloor and then raised to the surface. Zooplankton samples were then fixed in 10% formalin solution and stored aboard the ship.

In the lab zooplankton samples were filtered using a 103 µm sieve with tap water and split with a Folsom splitter. Depending on the concentration of zooplankton in the sample the 1/4 or 1/8 split were used. A 5 ml aliquot sample using a Stempel pipette was then used and placed in a Bogorov tray and counted under a dissecting microscope. 2-3 counts were made and average abundance was calculated using the equation:

$$\frac{Individuals}{m^3} = \frac{split\ number \times \left(\frac{sample\ volume}{aliquot\ volume}\right)}{net\ area \times length\ of\ tow}$$

Phytoplankton nets tows using a 153µm mesh and 26 cm diameter, were lowered 18 m and brought back to the surface sampling the euphotic zone. The samples were then fixed in Lugol's solution and stored aboard the vessel.

Phytoplankton samples were then analyzed in the lab using a compound microscope. Then processed using a 0.1 ml Palmer-Maloney slide and identified using, *A Taxonomic Guide to Some Common Marine Phytoplankton*, to genus level and then categorized as being solitary or chained (Horner 2002)**.** To calculate phytoplankton abundance, the equation used was:

$$\left(\frac{total\ cells}{volume\ of\ sample}\right) \times volume\ of\ original\ sample = \frac{cells}{volume\ of\ original\ sample}$$

then converted that to cells/m^3 by using the equation:

$$\left(\frac{cells}{volume\ of\ original\ sample}\right) \times \left(\frac{volume\ water\ filtered}{volume\ of\ original\ sample}\right)$$

For each sample 6 counts were conducted and processed in excel.

Phaeopigment

Chlorophyll was collected in 65 ml nontransparent bottles from Niskin bottles taken at varying depths from 50 m to the surface. The samples were then pumped across 25 µm filters, and then placed in 10 ml of 90% acetone before being frozen for around 24 hours. Chlorophyll concentrations were then analyzed from each sample using a flourometer then converted to phaeopigment using the equation:

$$Phaeo = \frac{\frac{\frac{F_0}{F_a}max}{\frac{F_0}{F_a}max - 1} \times K_x \left(\left(\frac{F_0}{F_a max} \right) (F_a) - (F_0) \right)}{volume\ of\ water\ filtered}$$

Where F0/Fa max is the ratio of F_0 to F_a for a sample, which contains only chlorophyll and no phaeopigments, which for this instrument the value was 2.153, and K_x is the calibration factor which was 0.05969 (Lorenzen, 1966).

Water properties

Depth profiles were created using a SB19+ CTD with rosettes and lowered roughly 10 m above the seafloor. Density plot were then created using Microsoft excel. Tide height data was collected through NOAA station 9449880 located in Friday Harbor, WA (https://tidesandcurrents.noaa.gov/stationhome.html?id=9449880). The proceeding tide was then determined to be the tide that would be most influential to the channel at the time the sample was collected. Tidal velocity was collected at a station located in Lopez Pass (48.4667° N, 122.8167° W) (http://tides.mobilegeographics.com/locations/3440.html).

Results

Zooplankton varied in abundance in both North and South stations. In North station on October 4th and 11th the concentration was roughly the same at 4.2×10^3 indv/m^3 on the 4th and 4.2×10^3 indv/m^3 on the 11th. This then decreased on the following cruises ranging from 2.1×10^3 indv/m^3 on October 28th and 1.9×10^3 indv/m^3 on November 9th (Figure 2a). In South station the pattern was different with the highest concentration occurring on October 4th with 4.9×10^3 indv/m^3. The concentration then decreased from October 11th to November 9th from 2.7×10^3 indv/m^3 to 2.1×10^3 indv/m^3.

Adult Calanoid copepods however stayed fairly constant in North station ranging from 1.1×10^3 indv/m^3 to 1.3×10^3 indv/m^3 with an outlier on November 1st with 814 indv/m^3 (Figure 3a). In South station the concentration of adult copepods was high on October 4th at 2.3×10^3 indv/m^3 then decreased on the later cruises maintaining a steady concentration ranging from 1.3×10^3 indv/m^3 to 1.6×10^3 indv/m^3 (Figure 3b).

Phytoplankton abundance at both stations North and South were variable throughout the cruises. The greatest abundance of phytoplankton was on October 11, 2016, with North station containing 7.75×10^4 cells/m^3 and South station containing 1.73×10^6 cells/m^3. The abundance then decreased in the later cruises falling to 1.31×10^5 cells/m^3 in North station and 8.64×10^4 cells/m^3 in South station on October 28, 2016. This decreasing trend persisted on the following cruises with the lowest abundance on November 9, 2016 in both North and South stations with 3641.31 cells/m^3 in the North and 3.20×10^4 cells/m^3 in the South. The cruise on October 4, 2016 North station had relatively low abundance at 6.60×10^5 (Figure 2). The low abundance was concurrent with a water column that was well mixed with density ranging from 22.80 kg/m^3 to 23.07 kg/m^3 (Figure 5).

In this study, all chain-forming phytoplankton, those with spines and those without were combined, as the species found formed long chains that also could inhibit grazing. North and South stations both had chained phytoplankton as being the most abundant throughout the sample dates (Figure 6). Although chained organisms were the most abundant, in North station there was an observed increase in solitary phytoplankton on October 11th with 2.4×10^6 cells/m^3 which was 30.51% of the overall sample (Figure 6a, 7a). This was followed by a low concentration in both solitary and chain forming phytoplankton. In South station there was a small increase in solitary on October 11th with 2.6×10^5 cells/m^3 but the overall percent of each cruise remained somewhat constant (Figure 6b, 7b)

The cruise on cruise 2 also produced the highest phaeopigment concentration at North station ranging from 0.24 µg/L at the surface to 0.19 µg/L at 50 m depth (Figure 8a). Phaeopigment concentration in South station decreased with time the greatest concentration being on October 4, 2016 with a range of 0. 0.25 µg/L at 20 m depth to 0.39 µg/L at 50 m depth (Figure 8b).

The proceeding tide and largest flood tidal exchange variable in both North and South stations. Flood tides influenced North station on October 11th and November 9th with the largest flood exchange being 1.9 m on both dates. Ebb tides influenced North station on October 4th and 28th as well as November 1st with the largest flood exchanges being 0.9 m, 1.2 m and 0.4 m. In South station the proceeding flood tides were on October 28th and November 1st with the largest flood exchange being 1.2 m and 0.4 m. The ebb tides in South station were on October 4th and 11th and November 9th with the largest flood exchanges being 0.9 m, 1.9 m and 1.9 m (Table 1).

Discussion

Grazing

Phytoplankton abundance in North and South station on October 11th was indicative of a bloom relative to the other cruise abundances (Figure 2). This bloom coincided with a large zooplankton abundance in North station as opposed to South station where zooplankton abundance decreased (Figure 2). Focusing first on North station, solitary phytoplankton were most abundant on October 11th consisting of 30% of the sample this is more significant due to the high abundance of phytoplankton in October as opposed to the following cruises (Figure 6a, 7a). Phaeopigment concentrations seem to suggest grazing as well as concentrations on October 11th are much larger at surface than the other cruises suggesting a stronger grazing presence on October 11th (Head 1996). Surface phaeopigment was examined more closely for this study than the phaeopigment deeper in the water column, as the more recent fecal matter containing the phaeopigment would be more prominent at the surface where grazing is occurring (Figure 8a).

For cruise 1 on October 4th there was a surprisingly low concentration of phytoplankton in North station (Figure 2a). This value was noticeable since South station's phytoplankton count was relatively high relative to the other phytoplankton samples in South station. One possible explanation could have been the presence of a mixed layer in North station (Figure 5) (Tian 2016). The mixed layer which extended beyond the euphotic zone could have distributed phytoplankton and fecal pellets containing phaeopigment deeper in the water column.

On October 28th and November 9th there was a high concentration of adult Calanoid copepods with a low phytoplankton concentration (Figure 2a, 3a). This observation could have been due to the zooplankton going into diapause or the Calanoids praying upon the nauplius resulting in the low nauplius concentrations seen in the last three cruises (figure 4a) (Laundry

1979). Another hypothesis could be that the low concentration of nauplii are due to them becoming adults and going into diapause.

South station however showed little evidence of strong grazing. Although grazing was occurring as shown by the phaeopigment on the cruise on October 4th, there were low abundances of phytoplankton throughout the sample dates (Figure 2b, 8b). In the last three cruises adult copepods were relatively constant with relatively low phytoplankton (Figure 3b). This was followed by a low concentration in nauplii thus indicating that the adult copepods were likely in diapause (Watson 1971, Laundry 1979).

Tidal influences on zooplankton

In this study, tidal variation during both flood tidal exchange as well as preceding tide had very little correlation to large zooplankton abundances. This is in contrast to what was found by Sigley (2012). The contrasting findings could not be explained by the data presented in this paper as well as Sigley's (2012).

Conclusion

There was a strong possibility that strong grazing pressure was observed in cruises 2 and possibly 1 in North station. Zooplankton and phytoplankton in both North and South stations decreased as fall progressed.

Although high zooplankton abundances were not linked to flood tides this year might be an anomaly as previous years this pattern has been observed. The gap between cruise 2 and 4 might have been too large to fully understand the relationship between the zooplankton and phytoplankton as the fall transition had occurred in between those cruses (Smith 2016).

Table 1:

Cruise Date	Previous Tide (North)	Previous Tide (South)	Largest Flood Tide Exchange (m)
4-Oct	ebb	ebb	0.9
11-Oct	flood	ebb	1.9
28-Oct	ebb	flood	1.2
1-Nov	ebb	flood	0.4
9-Nov	flood	ebb	1.9

Figure 1: Map of sample locations shown as black stars. The northern station west of Shaw Island is North station while the southernmost station located near Cattle pass is South station.

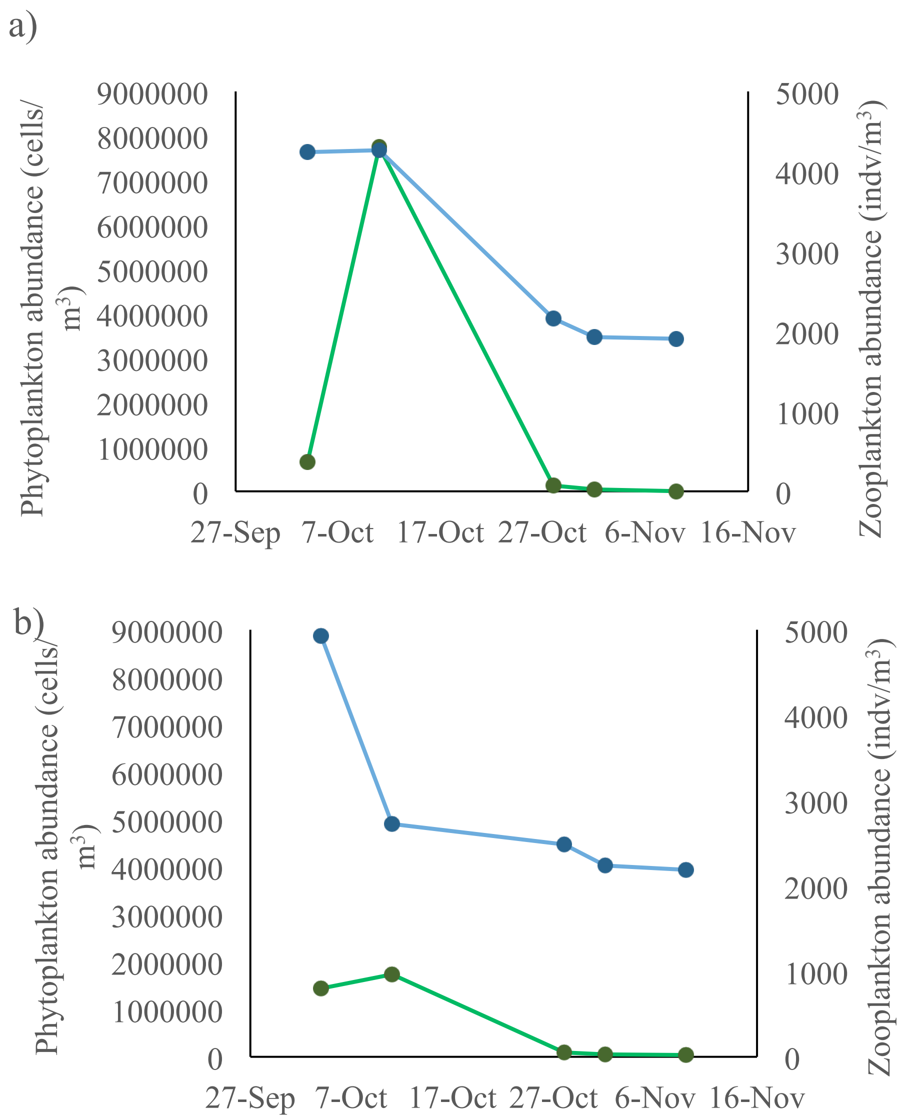
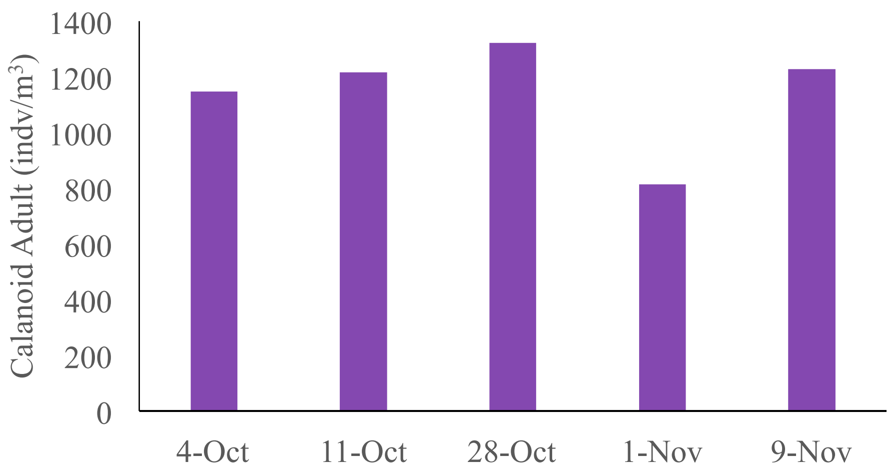


Figure 2: Both the zooplankton (individuals/m^3) and phytoplankton (cells/m^3) abundances in both North (a) and South (b) stations. The green lines are phytoplankton abundances while the blue line is zooplankton abundances. The x-axis is the period in which sampling took place.

a)



b)

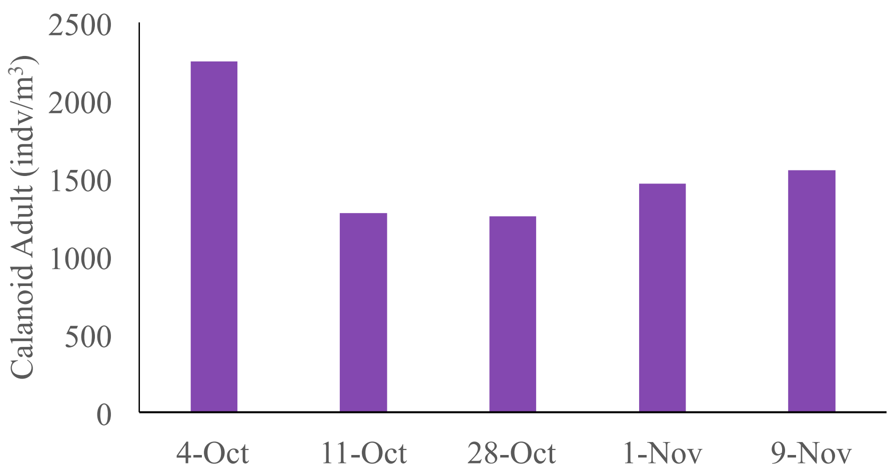
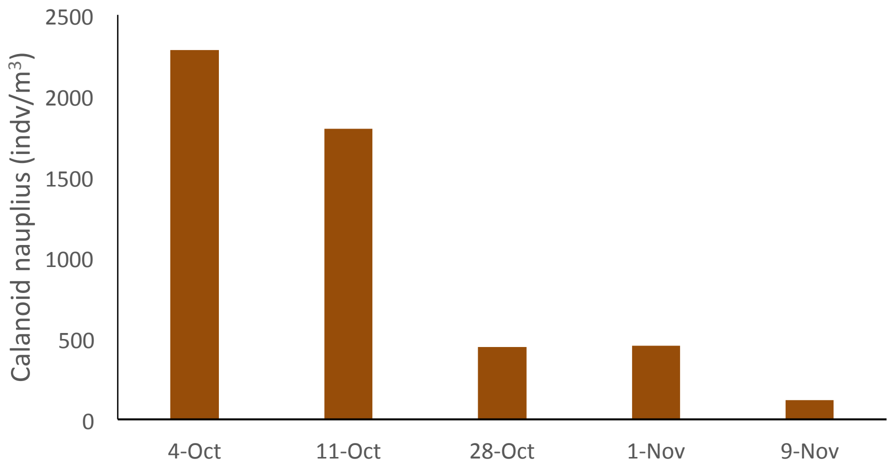


Figure 3: The adult calanoid copepod abundance (individual/m^3) of North (a) and South (b) stations. The sample date is on the x-axis.

a)



b)

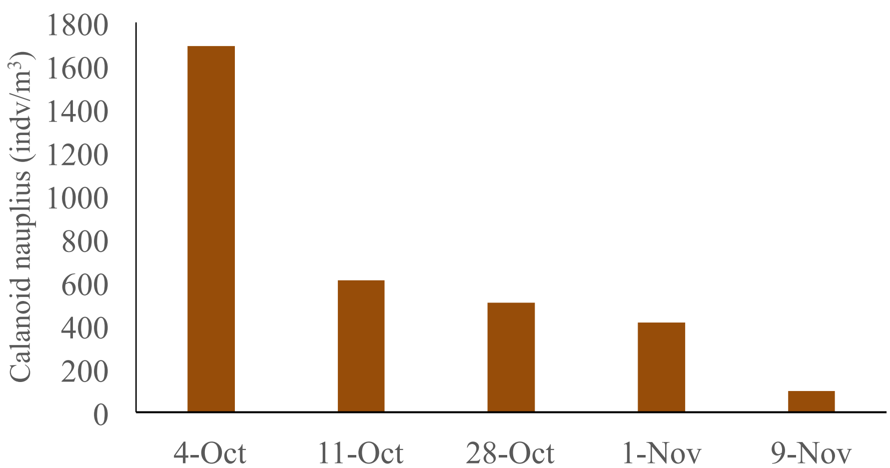


Figure 4: The copepod nauplius abundance (individual/m^3) of North (a) and South (b) stations. The sample date is on the x-axis.

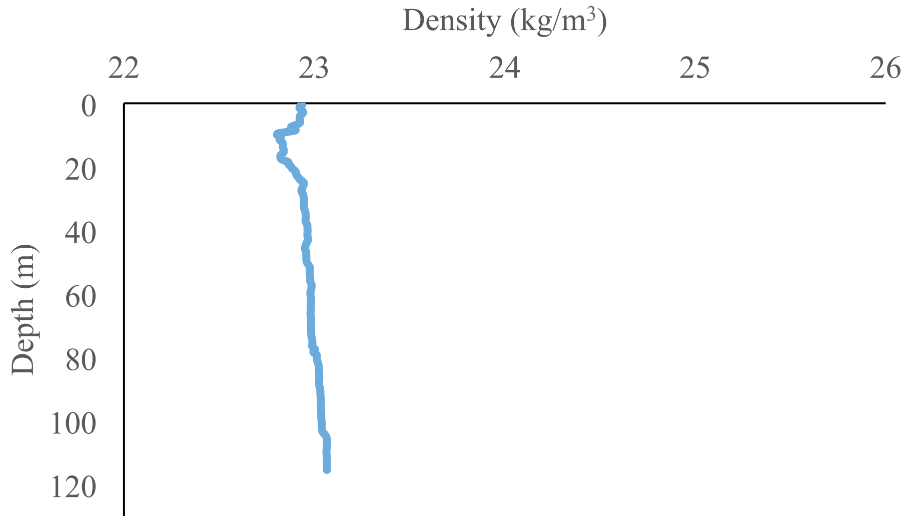


Figure 5: Density profile of North station cruise 1 on October 4, 2016. Where density (kg/m^3) is on the x-axis and depth (m) is on the y-axis.

a)

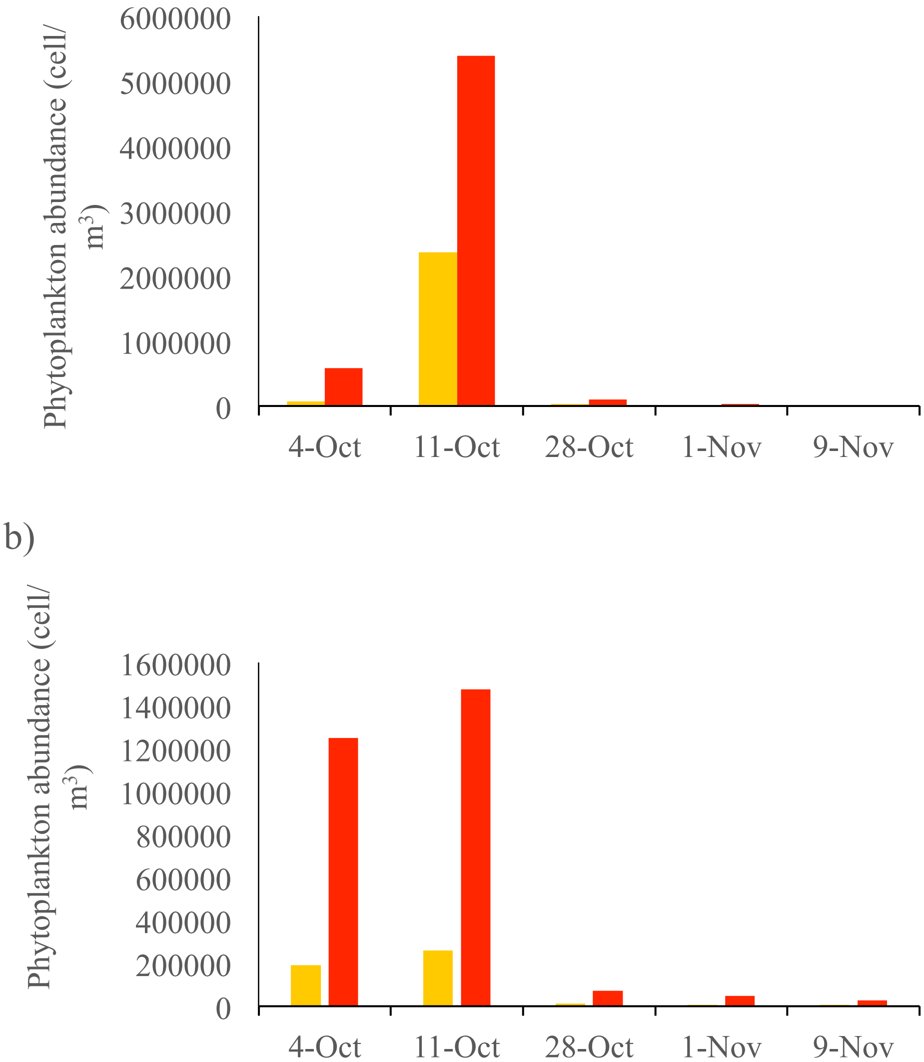
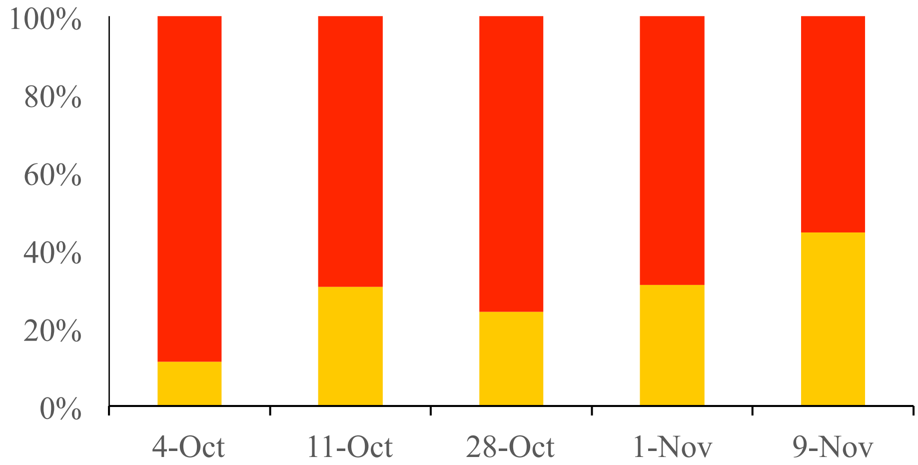


Figure 6: Phytoplankton abundances grouped into two categories: solitary (yellow) and chained (red). North (a) and South (b) stations' phytoplankton abundance were sectioned by dates the sample were collected.

a)



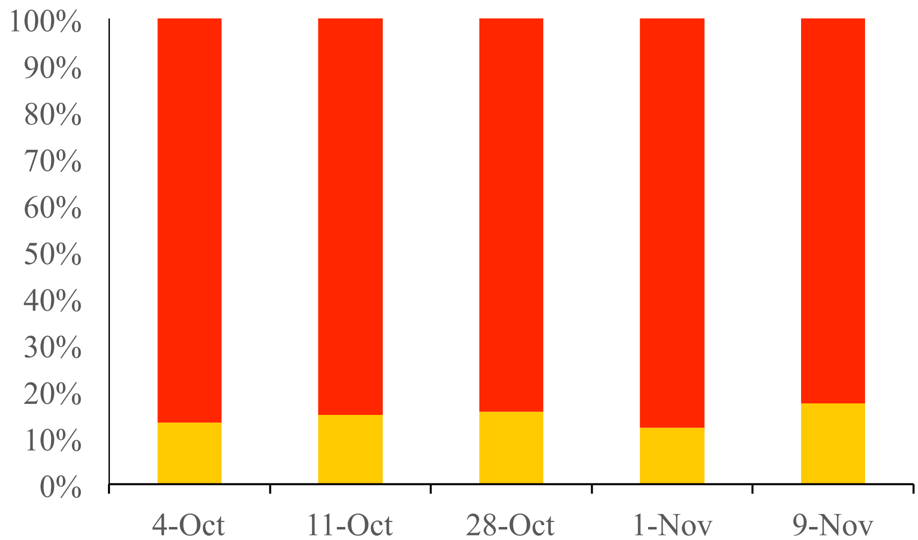
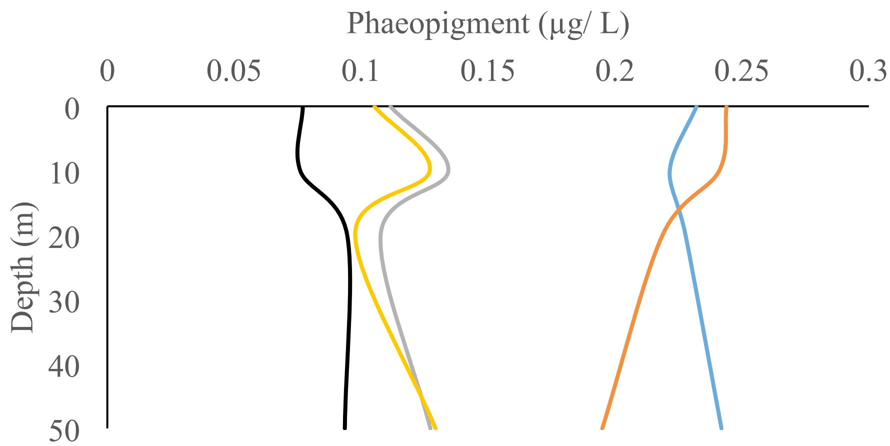


Figure 7: Phytoplankton abundance in both North (a) and South (b) separated into two categories: chained (red) and solitary (yellow). The y-axis is the percent of each category while the x-axis is the sample date.

a)



b)

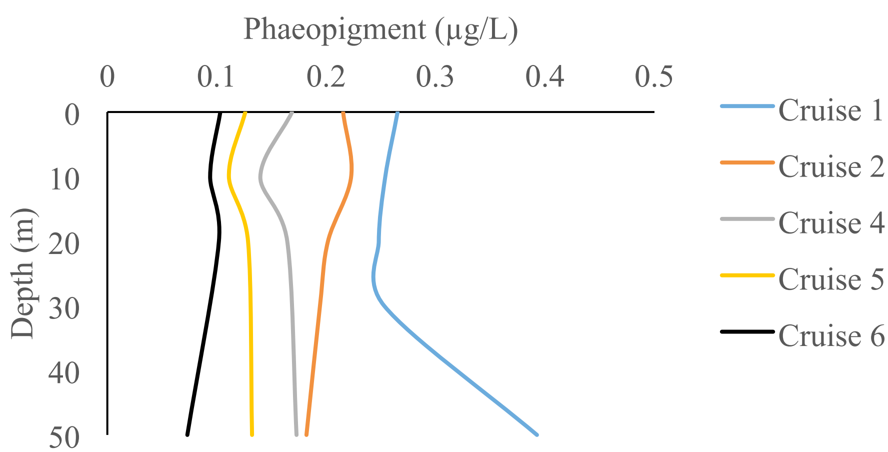


Figure 8: Phaeopigment concentration (µg/L) graphs in both North (a) and South (b) stations against depth. October 4th cruise in blue, October 11th cruise in red, October 28th cruise in gray, November 1st cruise in yellow, and November 9th cruise in black.

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