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High lipid composition of particulate organic matter in the northern Chukchi Sea, 2011

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ABSTRACT

We investigated the biochemical compositions (lipids, proteins, and carbohydrates) of particulate organic matter (POM) as a potential food source in the northern Chukchi Sea. We aimed to understand physiological status of phytoplankton, determine important controlling factors, and estimate the energetic contents of POM. The major inorganic nutrients were generally depleted at upper mixed-layer depth (>20 m). The average chlorophyll a (chl-*a*) concentration was 31.9 mg m^{-2} (S.D.= ± 31.3 mg m^{-2}) in this study, significantly higher than that reported previously in the northern Chukchi Sea. Small phytoplankton (0.7–5 μm) accounted for 65.9% of total chl-*a* concentration. The overall average compositions of lipids, carbohydrates, and proteins were 50% (S.D.= ± 10.7%), 35% (S.D.= ± 11.0%), and 15% (S.D.= ± 11.2%) for POM, respectively. Along with other evidence (e.g., low N:P and protein–carbohydrate ratios), the high lipid and low protein compositions of POM in this study suggests that phytoplankton might have had a nitrogen limitation and/or stationary growth phase in the northern Chukchi Sea during the cruise period, 2011. The overall average calorific content of food material (FM) was 149.2 μg L^{-1} (S.D.= ± 36.5 μg L^{-1}) or 1.0 Kcal m^{-3} (S.D.= ± 0.2 Kcal m^{-3}). The relatively higher calorific contents in the northern Chukchi Sea were due to high lipid contributions and the considerably high calorific content of FM per POC.

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1. Introduction

Phytoplankton are basic primary producers in marine food webs. They obtain energy through photosynthesis, chemical synthesis of organic compounds from carbon dioxide using sunlight. Their carbon is divided into three macromolecular classes: proteins, lipids, and carbohydrates. Earlier studies have reported how phytoplankton responds to changes in such environmental conditions as light, nutrients, salinity and temperature. Such changes determine phytoplankton's nutritional value (food quality) to herbivorous animals, which can affect secondary production as well as the higher trophic levels in marine ecosystems. Research has investigated phytoplankton incorporation of ^{14}C or ^{13}C into protein, lipid, polysaccharide, and low molecular weight metabolites (LMWM) during short or long incubation in regions including the Antarctic and Arctic Oceans (Smith and Morris, 1980; Morris, 1981; Priscu and Priscu, 1984; Rivkin and Voytek, 1987; Lindqvist and Lignell, 1997; Suárez and Marañón, 2003; Lee et al., 2007, 2009). Unfortunately, these studies have focused on either the physiologies of several species of phytoplankton from cultivated conditions, or patterns of short-term photosynthetic allocations. Although isotope-labeled carbon patterns in phytoplankton can reflect their physiological and nutritional status (Lee et al., 2009) at their exact growth moment, this is just a snapshot. Actually, phytoplankton continuously reallocate macromolecular compositions at night (Lancelot and Mathot, 1985). Instead, we are going to analyze composition patterns of proteins, lipids, and carbohydrates to reflect phytoplankton's longer-term responses to their environment (Marañón et al., 1995).

The Arctic Ocean shows most substantial alterations due to climate change worldwide. Increasing temperature has led to thinning, melting sea ice, affecting its marine ecosystem over the past several decades (Pabi et al., 2008; Matrai et al., 2013). These changes have altered the timing of phytoplankton spring blooms, the overall primary production, and the individual size and composition of benthic invertebrates, and the life histories of zooplankton (Arrigo et al., 2008; Li et al., 2009; Søreide et al., 2010; Grebmeier, 2012). In addition to the quantity of phytoplankton

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biomass, the quality of phytoplankton as a major food source could be changed. This study aims first to analyze compositions of macromolecular pools (proteins, lipids, and carbohydrates) of biopolymeric particulate organic matters (POM) in the northern Chukchi Sea. Its second goal is to find important environmental controlling factors for changes in these compositions, such as light and nutrients. The third goal is to estimate the energetic contents of biopolymeric particulate organic matter (POM), determining their food values to higher trophic organisms. This is the first work to analyze POM in the Arctic Ocean for potential food quality.

2. Materials and methods

2.1. Study area

We investigated fourteen stations in the northern Chukchi Sea between July and August 2011 (Fig. 1). At each station, we used the CTD system to obtain physical properties such as water temperature and salinity. Niskin were used for bottles collecting water samples using a CTD rosette sampler. Table 1 summarizes the characteristics of each station's location.

2.2. Phytoplankton chlorophyll a and nutrient analysis

Water samples for nutrient and chlorophyll a (chl-*a*) concentrations were collected using a CTD rosette sampler in the photic zone. A QuAAtro auto analyzer (SEAL Analytical, UK), used according to the manufacturer's manual, was used for determing the major dissolved inorganic nutrient concentrations (nitrite + nitrate, ammonium, silicate, and phosphate). We filtered water samples for measurements of total chl-*a* concentration through 25 mm GF/F (Whatman, 0.7 μm pore) and filtered them further by size with 20 and 5 μm membrane filters and 47 mm GF/F (Whatman, 0.7 μm pore). A Trilogy fluorometer determined concentrations of chl-*a* (Turner Designs, USA), after 24 h extraction in 90% acetone at 4 °C.

2.3. Particulate organic carbon and nitrogen analysis

We filtered seawater onto 25 mm GF/F (Whatman, 0.7 μm pore) for particulate organic carbon (POC) and particulate organic nitrogen (PON) measurements, immediately freezing the filters at −80 °C until analysis. We determined total POC and PON using a Finnigan Delta+XL mass spectrometer, after overnight HCl fuming to remove carbonate, at the stable isotope laboratory of University of Alaska Fairbanks.

2.4. Macromolecular compositions of POM

Water samples of POM were obtained from 3 light depths (100, 30, and 1%) during the second Korean Arctic cruise, 2011. Each one-liter seawater sample of proteins, lipids, and carbohydrates was filtered through a pre-combusted 47 mm GF/F filter (Whatman, 0.7 μm pore) and was then immediately stored at −80 °C

Table 1
Description of stations in the northern Chukchi Sea in 2011 (Water temperature, salinity, and integrated chl-*a* concentrations were averaged from surface to 100 m).

Station	Latitude (°N)	Longitude (°E)	Photic zone (m)	Water temperature (°C)	Salinity (‰)	Integrated chl-*a* (mg chl-*a* m^{-2})
St. 1	73.61	193.49	38	−1.21	32.01	93.29
St. 2	74.28	192.35	54	−1.24	30.89	183.52
St. 3	75.1	193.67	92	−1.25	30.58	7.38
St. 4	76.4	195.34	100	−0.71	30.19	3.91
St. 5	77.73	198.09	95	−0.65	30.26	4.8
St.6	78	191.69	84	−1.05	30.67	4.73
St. 7	78	188.04	87	−1.17	31.06	7.24
St. 9	77.98	180.69	79	−1.11	31.24	6.67
St. 11	77.98	173.98	60	−1.17	31.35	14.98
St. 13	76.4	174	57	−1.44	31.27	14.16
St. 15	76.4	180.66	81	−1.31	30.87	12.4
St. 16	76.4	183.97	81	−0.96	30.5	6.05
St. 17	77	188	98	−0.7	30.19	5.37
St. 18	76.29	192.84	98	−0.87	30.04	7.87

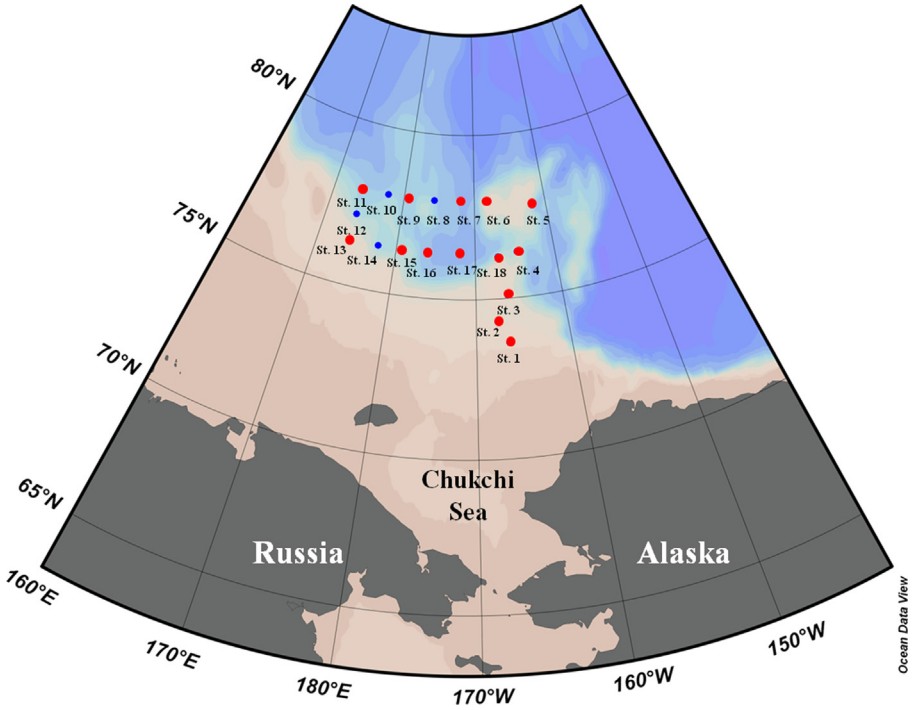

Fig. 1. Location of sampling area in the northern Chukchi Sea in 2011 (large closed circles: macromolecular stations).

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