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Bacterial community structure and functional potential in the northeastern Chukchi Sea

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ABSTRACT

We performed a molecular microbial ecological analysis in the northeastern Chukchi Sea in order to characterize bacterial community structure and genetic potential for biogeochemical cycling and oil biodegradation in a region targeted for oil and gas exploration (Burger lease area). Samples were collected from the surface, middle (20 m), and bottom (2–3 m above seafloor) of the water column during the open-water season of August and September 2012 at 17 different locations. We determined bacterial community structure with 16S rRNA genes sequencing and detected functional genes, including an array of oil biodegradation and biogeochemical cycling (carbon, nitrogen and phosphorus cycling) genes, using the GeoChip 5.0 microarray, and then correlated molecular data to contextual physical and biogeochemical factors. Bacterial community structure differed significantly by depth (surface water vs. bottom water) and between sampling dates (August vs. September). While the relative abundance of major functional gene categories did not differ with depth, the abundance of individual functional genes for carbon cycling, nitrogen cycling, organic contaminant remediation, phosphorus cycling, sulfur cycling, virulence, and viruses differed between surface and bottom seawater samples. Aerobic oil degradation genes and taxa known to include oil-degrading bacteria were found at all three depths. These findings support previous observations that two different water masses contribute to a stratified water column in the summer open-water season of the Burger lease area, but indicate that potential function is fairly similar with depth despite differences in temperature, water chemistry, bacterial community structure, and individual functional gene alleles.

1. Introduction

The potential for oil to be released into the environment is a prominent concern as marine traffic and offshore oil exploration activities continue to expand in the Arctic Ocean. The Burger prospect within the Chukchi Sea Lease Area 193 (herein after referred to as Burger) is located approximately 90 km offshore from Wainwright, Alaska, USA, and is a likely target for future development (Shell Gulf of Mexico Inc, 2015; Fig. 1). It is increasingly important to understand the ecology of this region as it responds both to a changing climate and potential oil and gas development. Microorganisms are critical to ecological function, thus baseline characterizations are important to understanding biogeochemical cycling, predicting the impacts of disturbance, aiding in predictions of oil biodegradation potential, and assessing recovery.

The structure and biogeochemistry of the Arctic marine ecosystem is defined by the presence of sea ice, inputs from its surrounding water masses, and associated stratification (Michel et al., 2012). The Chukchi Sea, a shallow sea (~50 m deep) located in the western Arctic Ocean, is linked to the Pacific Ocean by a northward flow through the Bering Strait. The long duration of summer sunlight and the Bering Strait's influx of heat, nutrients, carbon, and organisms drive the seasonally high productivity and strong benthic-pelagic coupling that characterize this region (Dunton et al., 2005; Grebmeier and Maslowski, 2014). This region is experiencing the effects of climate change (Grebmeier et al., 2006) as increasing seawater temperatures are leading to declines in sea ice (Comiso et al., 2008) and the subsequent increase of fresh water inputs into surface waters (Kwok and Cunningham, 2010; Michel et al., 2012; Serreze et al., 2007).

During the summer open-water season, salinity and temperature gradients associated with sea ice melt and dense winter water stratify the Burger water column (Weingartner et al., 2013a, 2013b). Water from the Bering Sea is thought to first displace melt water present in the upper portion of the Bunter water column and later the colder winder water occupying the lower portion (Weingartner et al., 2013a, 2013b). The co-occurrence of these different water masses typically

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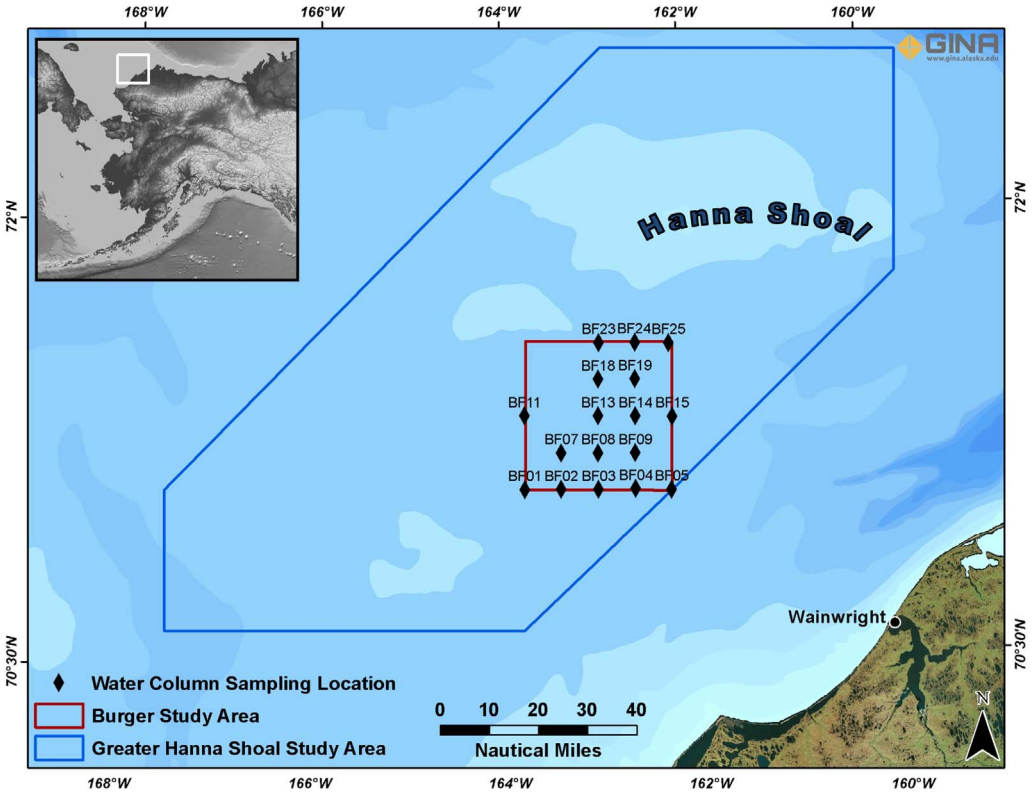

Fig. 1. The Burger lease area in the northeastern Chukchi Sea sampled during August 12–18 and September 20–22, 2012. Sampled stations are designated as black diamonds. At each station, water was collected from three depths: surface, middle (20 m from surface) and bottom (2–3 m from seafloor).

yields a continuously stratified water column with salinity and temperature gradients creating a thick (~5 m) pycnocline at a depth of approximately 15 m (Day et al., 2013; Weingartner et al., 2013a, 2013b). An important aspect of the benthic ecology of Burger is that the cold winter water generally persists in the benthic system throughout the summer open-water season (Day et al., 2013; Day et al., submitted for publication). The persistence of the winter water in Burger's benthic environment has been shown to vary seasonally and interannually and to affect many trophic levels (Day et al., 2013). These different water masses lead to differences in nutrient concentrations and zooplankton communities throughout the water column in the Chukchi Sea (Day et al., 2013; Blanchard et al., submitted for publication; Questel et al., 2013) and may also contribute to shaping the biodiversity and function of microbial communities important to biogeochemical cycling and the biodegradation of contaminants.

The Chukchi Sea has been the subject of extensive ecological and oceanographic studies (Gradinger, 2009; Hopcroft et al., 2010; Mathis et al., 2007; Weingartner et al., 2013a, 2013b), including assessments of oil biodegradation in near shore environments (McFarlin et al., 2014), yet to date very little is known about the microbial ecology of this region. A number of studies have investigated Arctic marine bacteria (Bano and Hollibaugh, 2002; Ferrari and Hollibaugh, 1999; Gomez-Pereira et al., 2010; Kellogg and Deming, 2009; Kirchman et al., 2010; Malmstrom et al., 2007; Monier et al., 2014; Pedrós-Alió et al., 2015; Pommier et al., 2007); however, neither microbial community structure nor functional genetic potential (including oil biodegradation genes and important biogeochemical processes) have yet been characterized in the Chukchi Sea. Even though no active oil seeps are known to exist in Burger (NRC, 2003), oil-degrading microorganisms are considered to be ubiquitous and are detectable in both polluted and unpolluted environments (Schneiker et al., 2006; Head et al., 2006; Yakimov et al., 2007; Kostka et al., 2011). Yet, little is known about the distribution of particular microbial taxa and genes associated with oil biodegradation in the Arctic marine environment, including along depth gradients within the water column, which is relevant to the fate of oil in the event of contamination.

Our objective was to obtain a detailed molecular analysis of the *in situ* structure of the bacterial community and its functional potential with regard to oil biodegradation and the cycling of carbon, nitrogen, phosphorus, and sulfur throughout the Burger water column. We also assessed the relationship between environmental factors (temperature, salinity, and nutrient concentrations) and both the structure and potential function of the microbial community to help identify important drivers of microbial community structure and the potential of specific biodegradation processes. We hypothesize that bacterial communities will differ between the distinctive upper and lower water masses, yet these genetically diverse communities will have similarly broad genetic potentials to cycle nutrients and degrade oil. These results may assist in developing an *in situ* baseline data set to assess ecosystem responses to environmental disturbances, while also providing insight into the potential for indigenous marine bacteria to degrade oil in a sensitive offshore Arctic environment.

2. Materials and methods

2.1. Study area

The Burger prospect within Lease Area 193 was the focus of this study. Lease Area 193, located in the Chukchi Sea (Arctic Ocean), contains an estimated 4.3 billion barrels of crude oil and gas (BOEM, 2015). Burger covers roughly 3000 km^2 of ocean with an average depth of ~40 m and has been the focus of extensive ecological studies for over 6 years (Blanchard et al., submitted for publication).

Hanna Shoal (~26 m in depth) borders Burger to the north (Fig. 1). The Hanna Shoal and its surrounding oil lease areas are some of the most comprehensively characterized sites in the Arctic Ocean. Measurements of oceanographic parameters defining the physical (Weingartner et al., 2005, 2013a, 2013b), chemical (Mathis and