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Distribution, abundance, biomass and diversity of benthic infauna in the Northeast Chukchi Sea, Alaska: Relation to environmental variables and marine mammals

Susan V. Schonberg^{a,*}, Janet T. Clarke^b, Kenneth H. Dunton^a

^a The University of Texas, Marine Science Institute, 750 Channel View Drive, Port Aransas, TX 78373, USA ^b Science Applications International Corporation (SAIC), Buckley, WA 98321, USA

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ABSTRACT

In summer 2009 and 2010, as part of Chukchi Sea Offshore Monitoring in Drilling Area - Chemical and Benthos (COMIDA CAB) program, we performed a quantitative assessment of the biomass, abundance, and community structure of benthic infaunal populations of the Northeastern Chukchi Sea. This analysis documented a benthic species inventory of 361 taxa collected from 142 individual van Veen grab samples (0.1 m⁻²) at 52 stations. Infaunal abundance was dominated by Polychaeta, Mollusca, and Crustacea. Large concentrations of bivalves (up to 1235 m⁻²; 920.2 gww m⁻²) were collected south of Hanna Shoal where flow from two water masses converge and deposit labile carbon to the seafloor, as indicated by low surface sediment C:N ratios. Amphipods (up to 1640 m⁻²; 26.0 gww m⁻²), and polychaetes (up to 4665 m⁻²; 114.7 gww m⁻²) were documented from multiple stations west of and within Barrow Canyon. This high productivity was most likely due to the "canyon effect", where marine and coastal detrital carbon supplies are channeled by the canyon structure, enhancing carbon deposition and flux, which supports rich benthic communities within the canyon and surrounding areas. To examine the relationships between infaunal distributions of all collected taxa with the physical environment, we used a Biota and Environment matching (BIO-ENV) routine. A combination of water depth, bottom-water temperature and salinity, surface sediment total organic nitrogen (TON) and sediment C:N molar ratios correlated closest with infaunal abundance distribution (ρ =0.54), indicating that multiple factors influence the success of benthic communities. BIO-ENV routines produced similar correlation results when performed on targeted walrus prey items (bivalves ($\rho = 0.50$), polychaetes ($\rho = 0.53$), but gray whale prey items (amphipods) were not strongly correlated to any combination of physical environmental factors (ρ =0.24). Distributions of primary prey items for gray whales (amphipods) and walruses (bivalves, gastropods and polychaetes) were compared with gray whale and walrus distribution as described by sightings from the 2009 and 2010 aerial survey component of COMIDA. In general, concentrations of walruses and their prey occurred in a swath located south of Hanna Shoal and on the shoal itself although the large differences in sea-ice distribution between the two study years showed that walrus distributions were closely linked to sea-ice location. Other areas within Barrow Canyon and the shelf west of the canyon showed high concentrations of benthic amphipods that were coincident with gray whale sightings as quantified by COMIDA aerial surveys. Overall, data collected on this project indicate that the Northeast Chukchi Sea supports a highly productive and diverse benthic ecosystem that is of significant importance to higher trophic level megafauna.

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1. Background

1.1. The benthos

The first reported oceanographic investigations of the Chukchi Sea were by the Swedish in 1878 (Leslie, 2011), followed by the Canadians in 1913 (Francis, 1986), the Norwegians in1922

E-mail address: susan.schonberg@utexas.edu (S.V. Schonberg).

(Amundsen, 1928), and the Russians in 1929, 1932, 1933, 1935, 1938, 1946, and 1976 (Sirenko and Gagaev, 2007). Americans joined the research effort in the 1970s, but these early U.S. studies were primarily focused on the Northern Bering Sea and Southern Chukchi Sea (e.g., Feder et al., 2005, 2007; Grebmeier, 1992, 1993; Grebmeier and Barry, 1991; Grebmeier and Cooper, 2008; Grebmeier et al., 1988, 1989, 2006a; Sirenko and Koltun, 1992; Stoker, 1978, 1981). The U.S. studies described diverse and productive [38–1800 g wet weight (gww) m⁻²] Grebmeier et al., 2006a) macrobenthic assemblages in the Northern Bering and the Southern Chukchi Seas, indicative of consistent high quality







^{*} Corresponding author. Tel.: +1 361 749 6728.

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organic marine matter deposition to the seafloor. The high benthic biomass in this region was attributed to nutrient rich waters supporting locally high primary production and vertical flux to the sea floor (Grebmeier et al., 1988, 1989).

In 1975, with the onset of proposed oil exploration on the Alaskan continental shelf, the U.S. Department of the Interior formed the Outer Continental Shelf Environmental Assessment Program (OCSEAP) to guide natural resource decisions concerning Alaskan oil development (Rose, 1982). A flurry of multi-disciplinary research efforts began along the entire Alaskan coastline, but few programs investigated the Northeastern Chukchi Sea region. Exploratory oil drilling began at five locations in the Northeastern Chukchi leases following Bid Sale 109 (1988) and Bid Sale 126 (1991), but no wells were placed into production (MMS-OCS, 2007; Fig. 1A, Historical Drill Sites). The 2008 Chukchi Sea Lease Sale 193, which generated nearly \$2.7 billion, renewed scientific research in the region as teams of scientists funded by Bureau of Ocean Energy Management (BOEM) and the oil industry (primarily Shell Exploration and Production Co., ConocoPhillips Alaska, and Statoil USA E & P; Day et al., 2013) collected information for required environmental impact statements (BOEM-OCS, 2011).

Prior to the 2008 lease sale, reported quantitative infaunal abundance and biomass from the Northeastern Chukchi Sea was primarily limited to a pair of OCSEAP supported surveys in the 1970s and 1980s by Stoker (1978, 1981) and Feder et al. (1989, 1994a, 1994b). Stoker's (1978, 1981) work was predominantly focused on the Northern Bering and Southern Chukchi Seas, but included 13 quantitative infaunal stations located within the Chukchi Sea Offshore Monitoring in Drilling Area - Chemical and Benthos (COMIDA CAB) study region. Feder et al. (1989, 1994a, 1994b) occupied a total of 37 stations in the Northeast Chukchi Sea. Our study, conducted under the COMIDA program (2009-2010), represents the first broad-scale quantitative survey of benthic infaunal species in the Northeastern Chukchi Sea since the surveys by Stoker (1978, 1981) in 1974 and Feder et al. (1989, 1994a, 1994b) in 1986. In a complementary paper, Blanchard and Feder (2014) assessed the macrobenthic community structure in three well-defined areas that encompass proposed industry drill sites within the Chukchi Sea Lease Sale 193 area.

Stoker (1978, 1981) determined that the Northern Chukchi Sea had lower standing stocks and higher diversity of infauna than the Northern Bering and Southern Chukchi Seas and that those infaunal distributions were primarily associated with sediment type. Subsequently, Feder et al. (1989) also concluded that infauna were most closely correlated to sediment type (% gravel–% sand–% mud), sediment organic carbon/nitrogen ratio (C:N), and sediment water content. However Feder et al. (1994a) found that infaunal abundance and biomass in the Chukchi Sea was greater north of 70°N due to the presence of a bottom front adjacent to Pt. Franklin. He also argued that water enriched with particulate organic carbon (POC) from the Southeast Chukchi Sea was advected northwards and carried nutrients that increased food availability to the Northeastern Chukchi benthos (Feder et al., 1994b).

1.2. Walrus and gray whales

Eastern Pacific gray whales (*Eschrichtius robustus*, Lilljeborg 1861) and Pacific walruses (*Odobenus rosmarus divergens*, Illiger, 1815) are benthic-feeding marine mammals that migrate to the Northeastern Chukchi Sea in summer as sea ice recedes. They remain until fall when sea ice reforms, at which point most gray whales migrate to the North Pacific (Rice et al., 1984) as walruses move south to the Bering Sea (Fay, 1982). Aerial surveys for marine mammals were conducted intermittently in the Northeastern Chukchi Sea from 1979 to 1988, funded by the Minerals Management Service (MMS). The main focus of those surveys (conducted from August to October) was the bowhead whale migration across the Alaskan Beaufort Sea (e.g., Ljungblad et al., 1987). Consequently, marine mammal data collected in the Chukchi Sea remained sparse until the late 1980s.

Following Bid Sale 109 in 1988, broad-scale marine mammal aerial surveys in the Northeastern Chukchi Sea were conducted from 1989 to 1991 from late September through early November (Moore and Clarke, 1992). From 1982 to 1991, gray whales were generally seen nearshore between Pt. Barrow and Pt. Lay, near Pt. Hope, and offshore near Hanna Shoal. Most gray whales were observed feeding, presumably on amphipods, as evidenced by the presence of mud plumes (Moore and Ljungblad, 1984). Habitat preferences of gray whales are typically shallow nearshore or shoal waters (Moore et al., 2000).



Fig. 1. (A) Sampling stations (circles) denote infaunal van Veen grab sample locations during the 2009 and 2010 COMIDA field surveys. Triangles indicate locations of historical drill sites from 1989 to 1992 (MMS-OCS, 2007). The Chukchi Sea Lease Sale 193 area is denoted by a solid dark purple line. (B) General water circulation patterns in the Northeast Chukchi Sea (adapted from Day et al. (2013)). The dashed orange line is a proposed graphic representation of clockwise circulation of winter water in some years, based on model predictions and limited observations reported by Weingartner et al. (2013).

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