Effects of Environmental Change on Planktonic Associations in the Northern Bering and Chukchi Seas

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Background and Approach

The Northern Bering and Chukchi Seas are undergoing unprecedented oceanographic changes including increasing temperatures and shortening of the sea-ice covered season. These changes impact planktonic communities as evidenced by recent changes in primary production, timing of phytoplankton blooms, and in phytoplankton and zooplankton size structure and species composition throughout the region[1]. Changes in planktonic communities affect trophic interactions, energy pathways, and benthic-pelagic coupling, potentially altering the entire structure of Arctic marine ecosystems and the services they provide to human communities.

Here we use concurrent samples on mesozooplankton, phytoplankton, micro-zooplankton, and oceanographic conditions from four Arctic Integrated Ecosystem Research Program (Arctic IERP) surveys to understand mechanistic associations among planktonic communities and the physical environment in the Northern Bering and Chukchi Seas during 2017—2019, an unprecedented warm period. Understanding these associations is critical to predicting zooplankton and ecosystem-wide responses to climate change.

Oceanographic Conditions

Oceanographic conditions varied between seasons and years. In spring, the region was characterized by warmer waters in 2017 than 2018 (**Fig. 1**) with a predominance of warm Shelf Water in 2017 and nutrient-rich Anadyr and cool Shelf Water in 2018 (**Fig. 2**). In summer of 2019, significantly warmer and fresher waters compared to 2017 (**Fig. 1**) were associated with a predominance of warm Coastal Water over the Chukchi Sea shelf that resulted in shallower mixed layer depths and lower nutrient concentrations (**Figs. 1** and **2**).

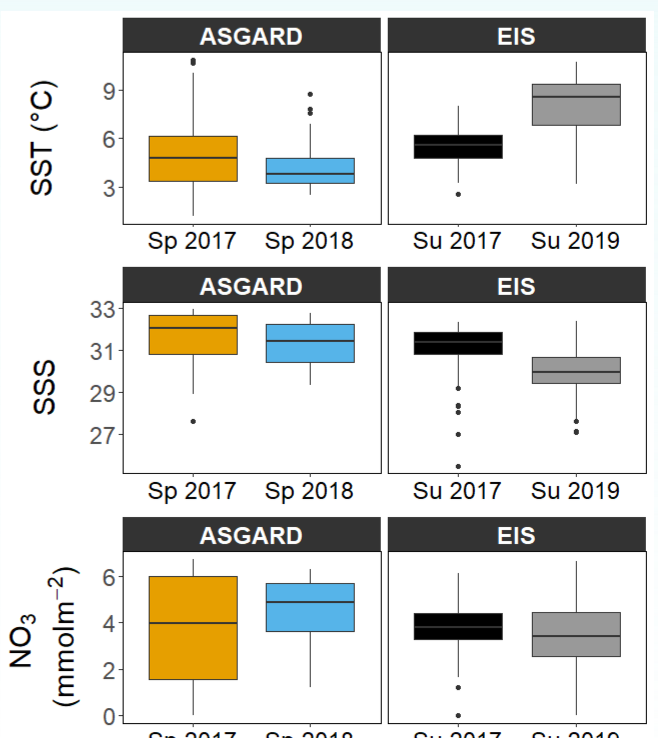


Figure 1. Average sea surface temperature (SST) and salinity (SSS), and water column integrated nitrate concentrations (NO_3) in the Northern Bering and Chukchi Seas in springs of 2017 and 2018 (ASGARD) and summers of 2017 and 2019 (EIS).

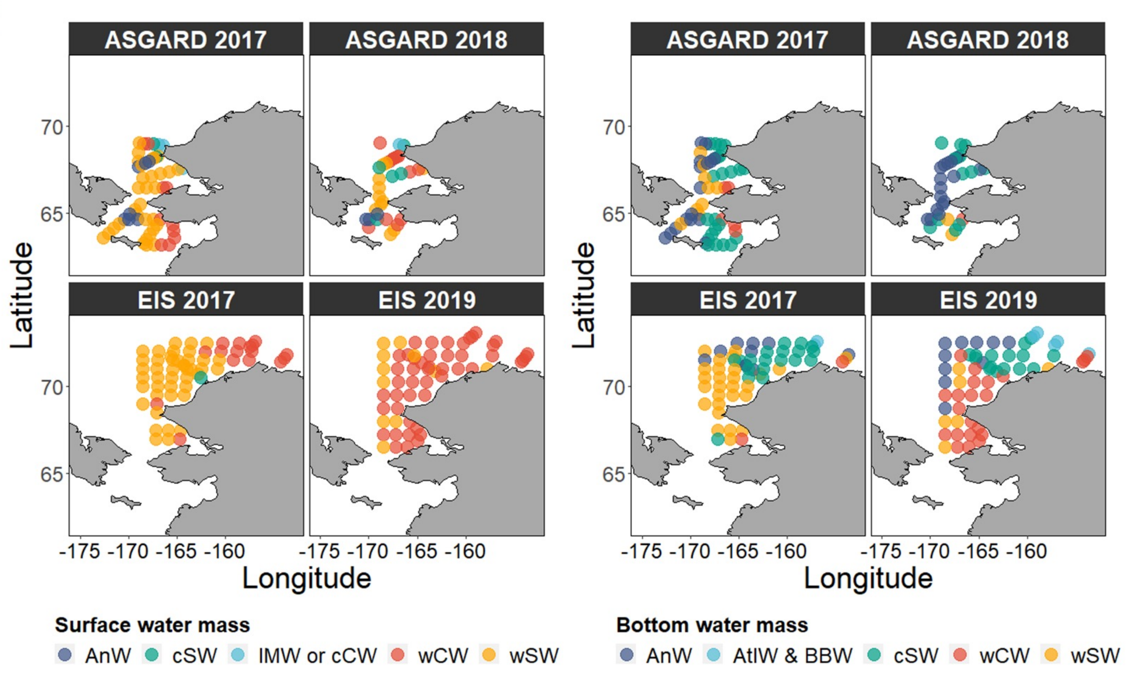


Figure 2. Predominant surface and bottom water masses[2] in springs of 2017 and 2018 (ASGARD) and summers of 2017 and 2019 (EIS). AnW: Anadyr Water, cSW: cool Shelf Water, IMW: Ice Melt Water, cCW: cool Coastal Water, wCW: warm Coastal Water, wSW: warm Shelf Water, AtlW: Atlantic Water, BBW: Bering Basin Water.

Phytoplankton and Microzooplankton Distributions

Lower temperatures and higher nutrient concentrations in spring of 2018 resulted in higher chlorophyll-a and micro-zooplankton concentrations throughout the region compared to 2017 (**Fig. 3**). Particularly warm summer conditions in 2019 were characterized by a pre-dominance of smaller phyto-plankton cells (e.g. *Synechococcus*), mainly in areas with warm Coastal Water (**Fig. 3**), and overall lower microzooplankton concentrations.

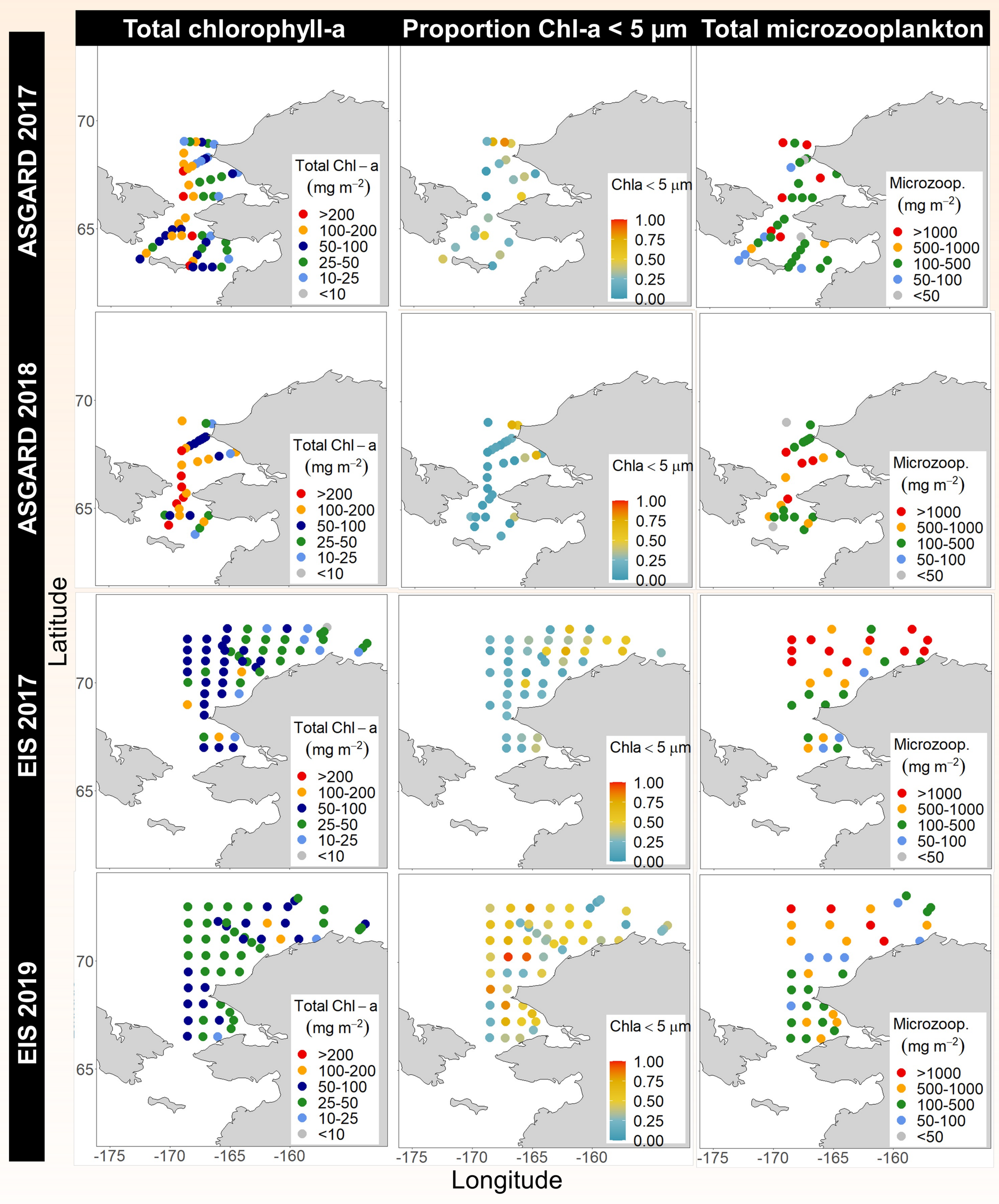


Figure 3. Integrated total chlorophyll-a, proportion of chlorophyll-a in > 5 μm size fraction, and integrated total microzooplankton (ciliates + dinoflagellates) concentration observed in springs of 2017 and 2018 (ASGARD) and summers of 2017 and 2019 (EIS).

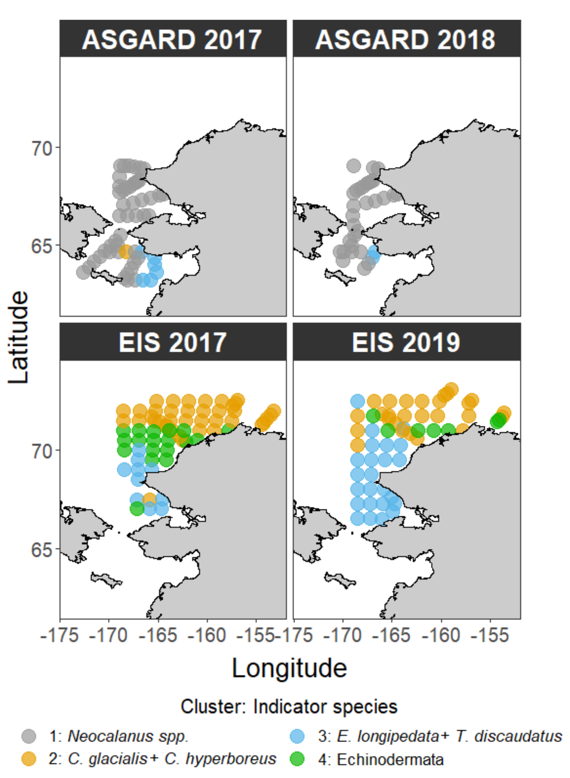
Spatial Structure of Zooplankton Communities

Zooplankton species composition varied mainly along longitudinal/salinity (northern Bering Sea) and latitudinal/temperature (Chukchi Sea) gradients (**Figs. 4** and **5**). Zooplankton assemblages characterized by Pacific-origin species (Cluster 1) and cold water copepods (Cluster 2) were restricted to spring and northern Chukchi Sea stations, respectively **(Fig. 4)**. Differences in the spatial extent of assemblages associated with warm Coastal Water (Cluster 3) and with warm Shelf Water (Cluster 4) between summers of 2017 and 2019 (**Fig. 4**) are attributed to interannual variations in the intrusion of the Alaskan Coastal Current into the Chukchi Sea shelf.

Table I. List of taxonomic groups included in the multivariate analyses, gear (mesh size, μm), and taxon abbreviation.

Taxa	Gear	Abbreviation
Acartia spp.	150	AC
Bivalvia	150	BI
Centropages spp.	150	CP
Cirripedia	150	CI
Echinodermata small	150	ECS
Fritillaria spp.	150	FR
Oikopleura spp. Small	150	OK.S
Oithona spp.	150	OI
Polychaeta small	150	PS
Pseudocalanus spp.	150	PC
Calanus glacialis	150/505	CG
Epilabidocera longipedata	150/505	EL
Eucalanus bungii	150/505	EB
Euphausiacea	150/505	EU
Metridia spp.	150/505	ME
Neocalanus spp.	150/505	NE
Tortanus discaudatus	150/505	TD
Aglantha digitale	505	AD
Brachyura	505	BR
Calanus hyperboreus	505	CAH
Chaetognatha	505	CH
Echinodermata large	505	ECL
Limacina helicina	505	LH
Oikopleura spp. Large	505	OK.L
Paguridae	505	PA
Polychaeta large	505	PL
Thysanoessa spp.	505	TH

Figure 4. Horizontal distribution of the four groups identified from a Bray-Curtis similarity index based on zooplankton abundance data during springs of 2017 and 2018 (ASGARD) and summers of 2017 and 2019 (EIS). Indicator taxa for each cluster are shown.



Planktonic and Environmental Associations

Associations among planktonic communities and the environment varied between seasons. Zooplankton species composition (**Fig. 5**) and total abundances (**Fig. 6**) were correlated with salinity in the northern Bering Sea in spring as sea ice retreats and with temperature in the Chukchi Sea in summer, with warmer waters favoring smaller zooplankton and colder and more saline conditions favoring larger zooplankton. The correlation between ciliates and temperature varied between spring and summer probably as a response to changes in chlorophyll availability. In spring, there is a negative correlation between chlorophyll and ciliates likely indicating high grazing pressure of ciliates on phytoplankton.

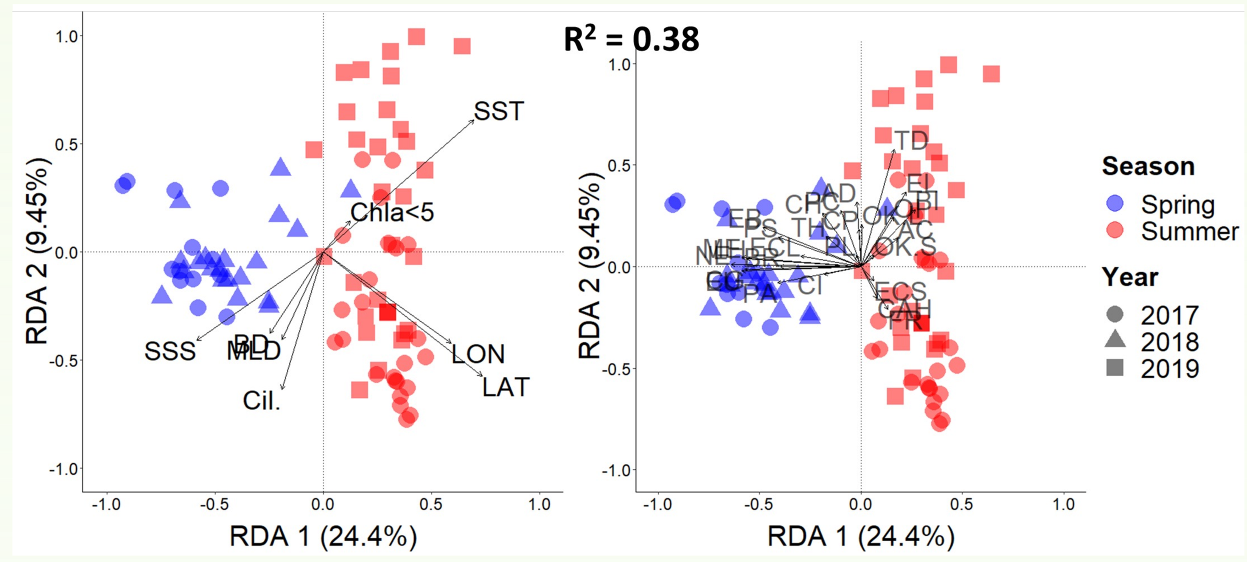


Figure 5. Redundancy analysis plots showing environmental variables (left) and zooplankton taxa (right) including stations from all cruises. Each data point represents a station. SST: sea surface temperature, SSS: sea surface salinity, BD: bottom depth, LON: longitude, LAT: latitude, Cil.: integrated ciliate concentration, MLD: mixed layer depth, Chla<5: integrated chlorophyll-a <5 μm size fraction. See table I for zooplankton taxa abbreviations.

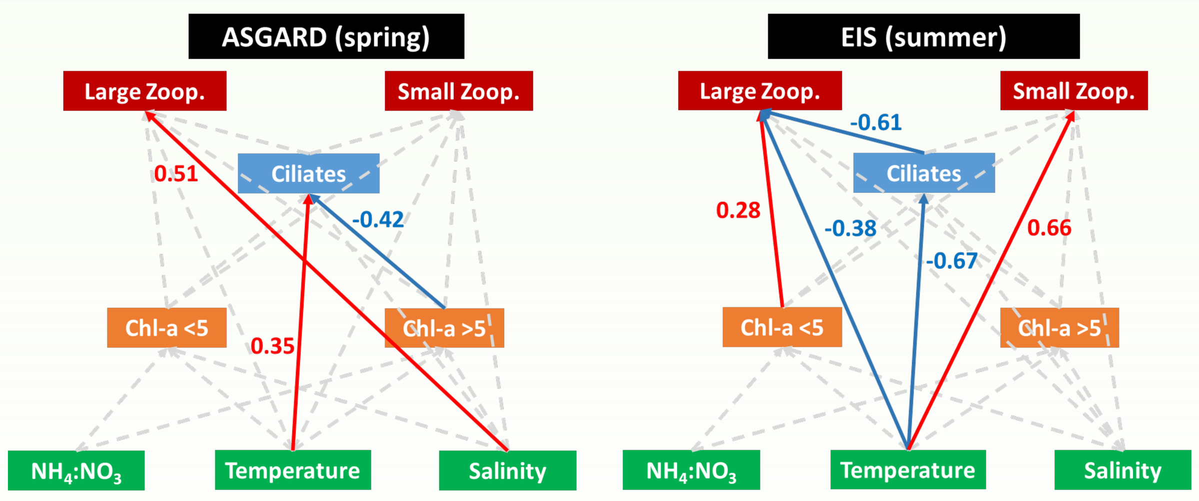


Figure 6. Structural equation model path diagrams showing standardized correlation coefficients for significant associations. Significant negative correlations are highlighted in blue and positive correlations in red. Water column mean temperature, salinity, nitrate and ammonium, integrated chlorophyll-a size fractions (< 5 μm and > 5 μm) and ciliates, and small (150 μm net) and large (500 μm net) zooplankton abundances were included in the model.

SO WHAT?

Warming and increasing inflow of warm Coastal Water into the Chukchi Sea is associated with smaller sized phytoplankton (e.g. Synechococcus) and smaller sized zooplankton. Shifts towards smaller planktonic organisms can affect trophic transfer efficiencies with cascading effects on food webs potentially impacting commercial and subsistence fish and shellfish resources and benthic-pelagic coupling of these ecosystems.

Acknowledgments

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