The northern shift of Pacific zooplankton follows the temperature of Bering Summer Water in the Chukchi Sea

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ABSTRACT

The Bering Strait is the only gateway to the Arctic Chukchi Sea from the Pacific Ocean and is a major route to the influx of Pacific water. The recent oceanographic changes, such as rising water temperatures and shifting sea ice cover, have resulted in sub-polarization of zooplankton communities from the Arctic boundary. We collected zooplankton at 13 stations in the Chukchi Sea and Bering Strait in 2014-16. In addition, the mooring systems installed at the Bering Strait were analyzed to obtain water temperature and salinity data for the corresponding period. As a result, the abundance of Pacific zooplankton species (*Eucalanus bungii, Metrida pacifica*, and *Neocalanus* spp.) was high in 2015, and water temperature and salinity were also high. In particular, water mass analysis showed that the temperature of Bering Summer Water (BSW) was high. On the other hand, Pacific species were rarely found in 2014 and 2016, and water temperature and salinity were relatively low. In conclusion, the Pacific species introduced into the Chukchi Sea were known to flow along the BSW, but the Pacific species showed high abundance only in the relatively high temperature (> 3 °C) of the BSW.

BACKGROUND

The water masses that flow through the Bering Strait are basically classified into three types (Coachman et al., 1975; Stabeno et al., 2018; Woodgate et al., 2005): Alaskan Coastal Water (ACW), Bering Sea Water (BSW), Anadyr Water (AW). The definition and classification criteria of the water masses of the study area, Bering Strait and the Chukchi Sea, are somewhat different from one study to another. In particular, the ranges and sub-categorization criteria of water mass called Bering Sea Water or Bering Summer Water are very diverse (e.g. Coachman et al., 1975; Corlett and Pickart, 2017; Danielson et al., 2017; Ershova et al., 2015). We determined that the classification of Corlett and Pickart, 2017 among the water masses classification is appropriate for our study area and data.

RESULTS

The zooplankton samples were collected from Bering Strait and Chukchi Sea in August 2014-16. As a result, Pacific zooplankton species (*Eucalanus bungii, Metrida pacifica*, and *Neocalanus* spp.) were found in the study area (Fig. 2). Especially in 2015, more than 1,000 individuals per m^3 of Pacific species appeared, but rarely appeared in 2014 and 2016. We tried to compare the data of surface water temperature, salinity and CTD vertical data acquired together at the collection stations to find the reason for the emergence of Pacific species in this area, but we could not get meaningful results. Therefore, we obtained more long-term physical data from the mooring data in the Bering Strait (Fig. 1). In this mooring data, long-term temperature and salinity data were obtained for about 20 days including the time of collecting zooplankton in 2014-16.

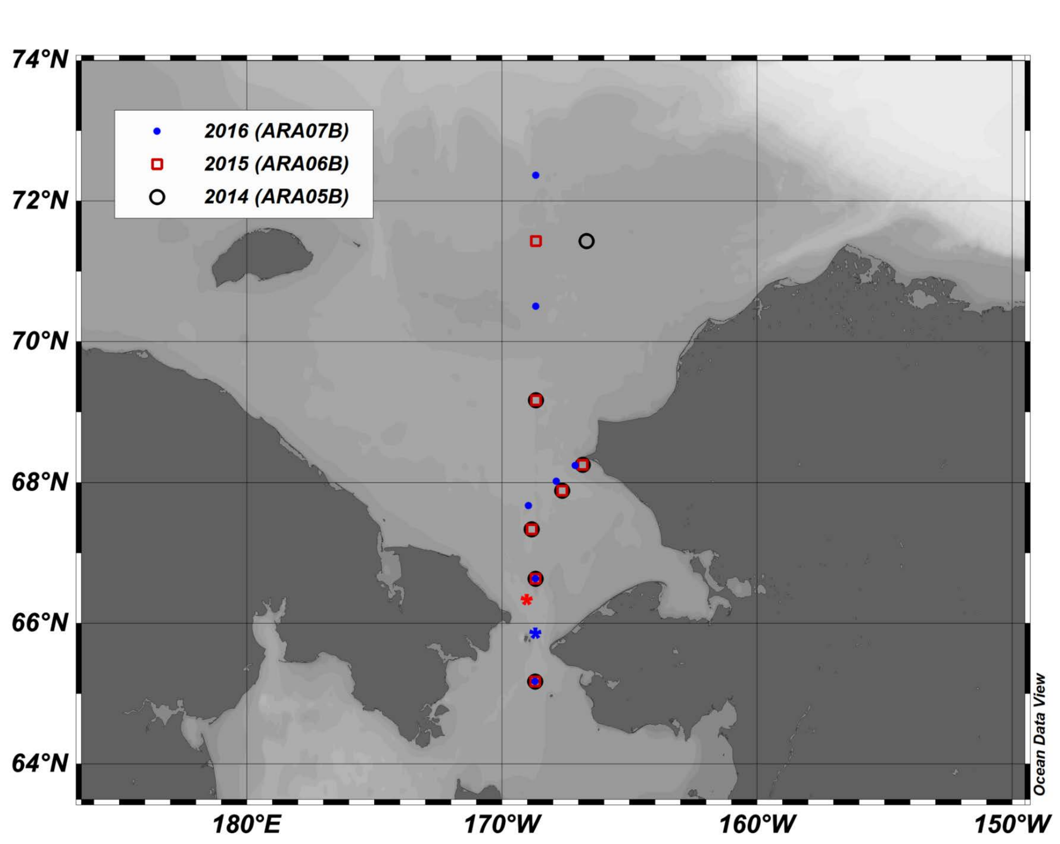

Figure 1. Map of study the area with station locations represented by blue dots (2016), red squares (2015), and black circles (2014). A blue asterisk is A2 mooring location, and a red one is A3.

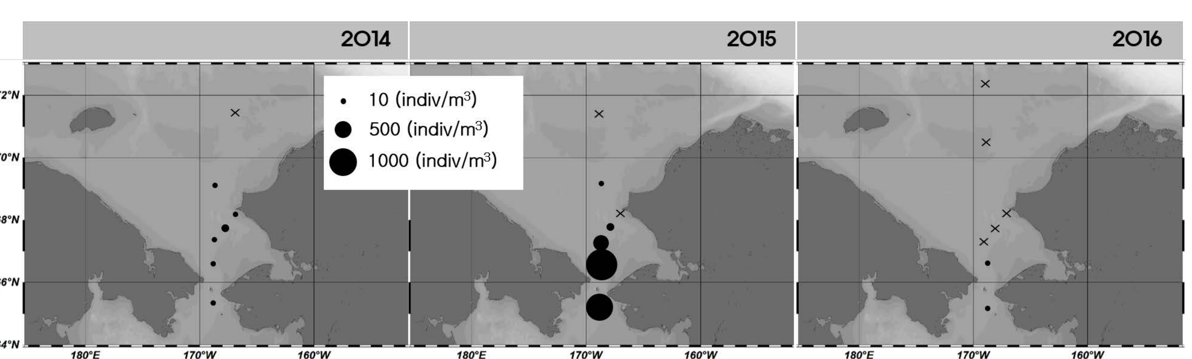

Figure 2. Proportional abundance plots (indi. m^{-3}) of Pacific zooplankton species in the Chukchi Sea. *Eucalanus bungii, Metrida pacifica*, and *Neocalanus* spp. combined.

The T-S diagram consisting of the water temperature and salinity data from the mooring data (Fig. 3) shows that the composition of the water masses in this region is based on the Pacific summer waters ACW and BSW (Corlett and Pickart, 2017 classification). In particular, the data from the A3 mooring facility, located in the northern part of the Bering Strait, consisted mainly of BSW throughout the study period. In 2015, when the Pacific species appeared a lot, the water temperature and salinity were relatively high, especially the temperature of BSW was high. On the other hand, relatively cold BSW waters were introduced into the Bering Strait in 2014 and 2016, particularly in 2014, high water temperature ACW was introduced, but Pacific species rarely appeared. The ACW is relatively dense and flows upwards and the high-density BSW flows downward, so the difference in data is more apparent when looking at the bottom of the mooring data. The mean water temperature data of Fig. 4 shows that the BSW in excess of 3 °C was introduced into the Chukchi Sea in 2015 when the Pacific species were abundantly present. In the other years, less than 3 °C BSW waters were introduced. The data of 2014, when high water temperature ACW was introduced, indicate that the emergence of Pacific species is not related to simple water temperature, but is related to the water temperature of BSW.

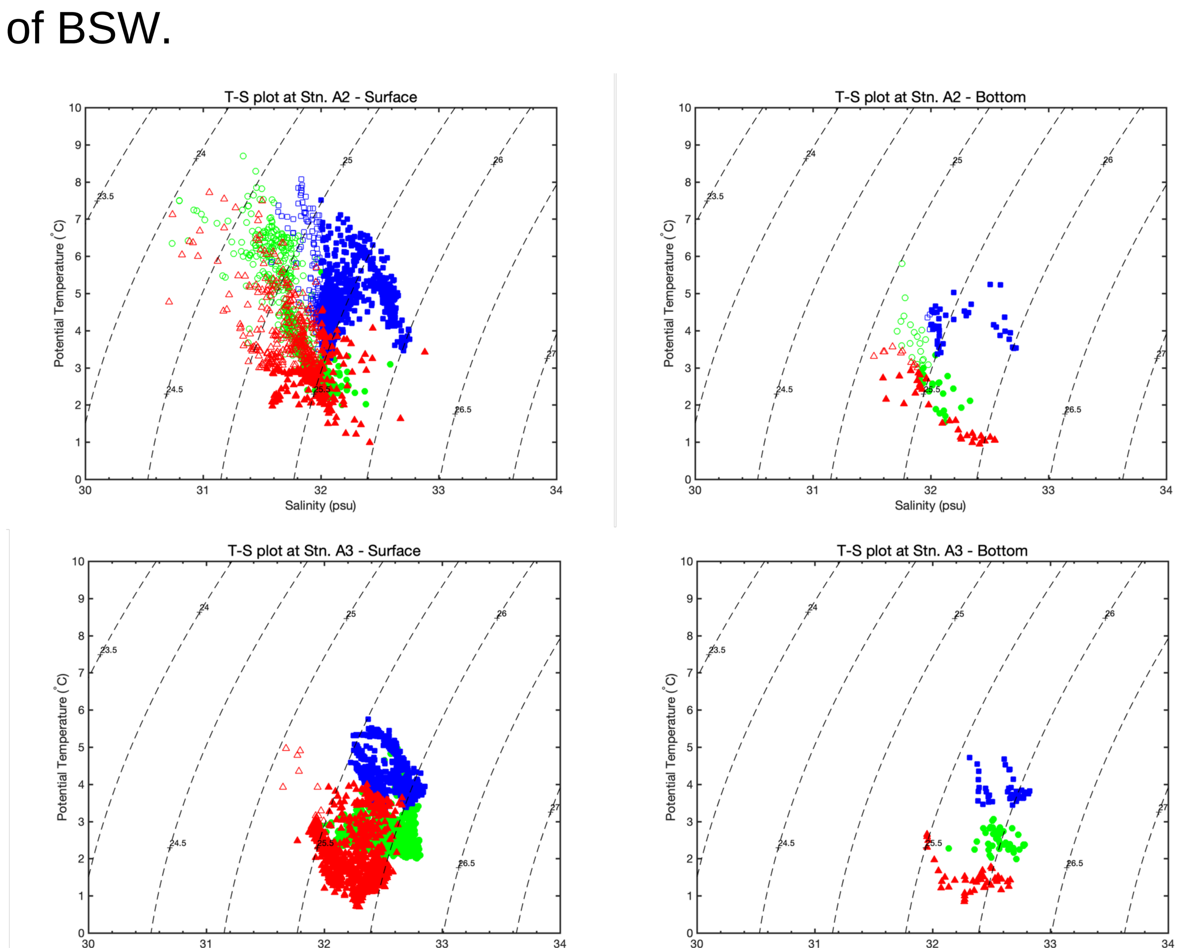

Fig. 3. A2, A3 mooring T-S Diagram for 20 July – 10. August 2014-6. The shapes filled with color are BSW, and the shapes with an empty color are ACW (Green circles: 2014; Blue squares: 2015; Red triangles: 2016).

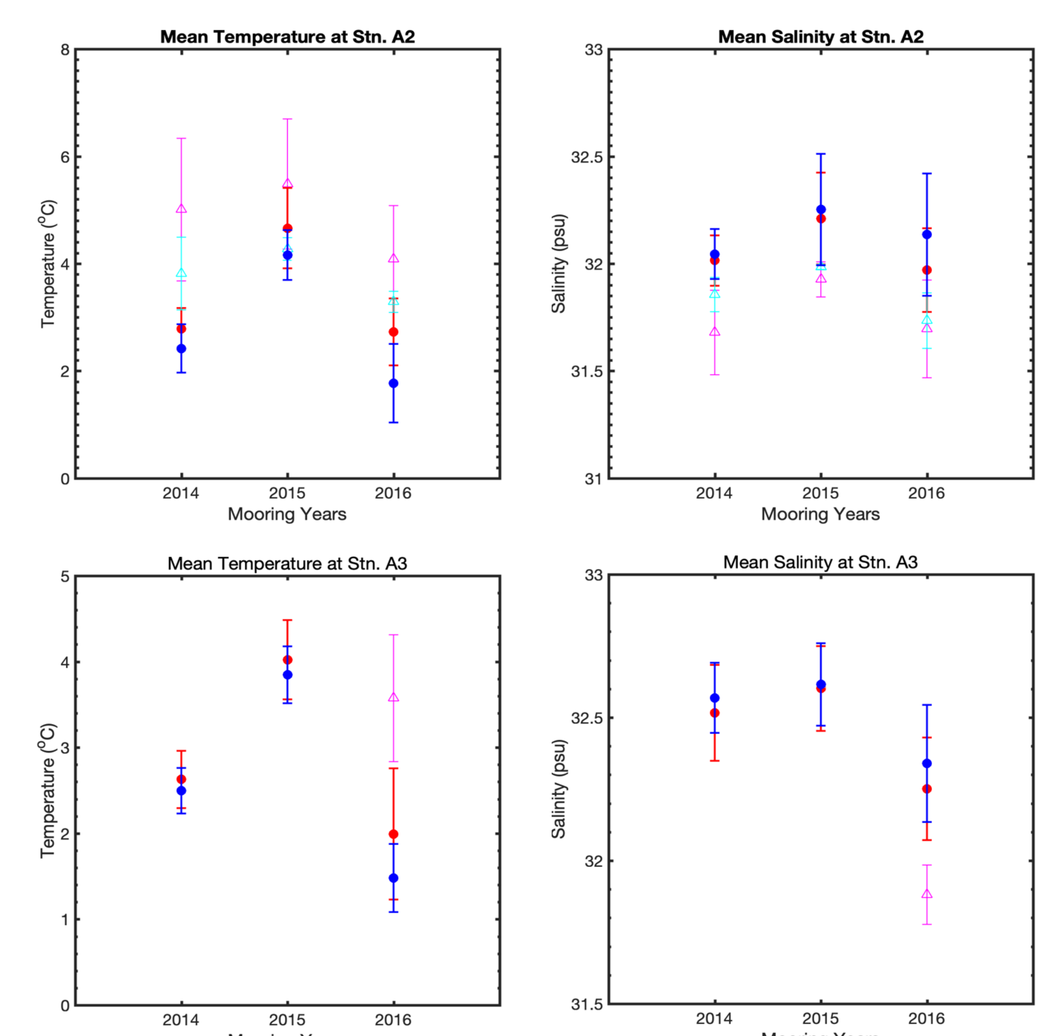

Fig. 4. A2, A3 mooring mean T, S for 20 July – 10. August 2014-16. Red circles: BSW surface; Blue circles: BSW bottom; mauve triangles: ACW surface; cyan triangles: ACW bottom.

CONCLUSIONS

In our 2014-16 data BSW dominated the Bering Strait every year and the Pacific species only appeared a lot in 2015. This means that the emergence of Pacific species cannot be explained simply by the influx of BSW. In results, Pacific species appeared in the Bering Strait and southern part of the Chukchi Sea when a relatively warm (about 3 ° C or more) BSW was introduced.

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