BEST-BSIERP
Bering Sea PROJECT
UNDERSTANDING ECOSYSTEM PROCESSES IN THE BERING SEA 2007–2013

Return of the Zooplankton

RECENT COLD CONDITIONS A BOON FOR CRUSTACEAN ZOOPLANKTON

Copepods (e.g., *Neocalanus cristatus*) and krill (e.g., *Thysanoessa inermis*) are miniature shrimp-like animals that are critical to the diets of commercially valuable fish, marine birds and cetaceans. They are an essential link between the base of the marine food web and larger animals. But the population of these large crustacean zooplankton (LCZ) in the Bering Sea varies depending on ocean conditions. The population of LCZ crashed during a string of years with warmer water (2000-2005), and has recovered in recent years as water temperatures cooled (Figure 1).

What caused such a large swing in LCZ population? Was there insufficient food during the warm years (less phytoplankton and tiny micro-zooplankton), or was there more grazing from fish and mammals keeping LCZ populations low? And how are such changes in the food web linked to changes in climate and ocean circulation?

How We Did It

Our approach was to analyze bottom-up (food supply) and top-down (predation by fish) controls of LCZ standing stocks, including climate, physics, primary production, micro-zooplankton production, and predation, and to examine how LCZ production was partitioned among top predators under varying climate scenarios. Because the eastern shelf has different physical domains (regions with different ocean properties) these questions were examined in defined regions of the shelf to elucidate how differences in water column structure and mixing processes affect the flow of carbon and energy.

Using data from the past decade, we examined spatial and temporal distributions of predator and prey fields, and the influence of climate and currents on those distributions. Hypotheses and questions were

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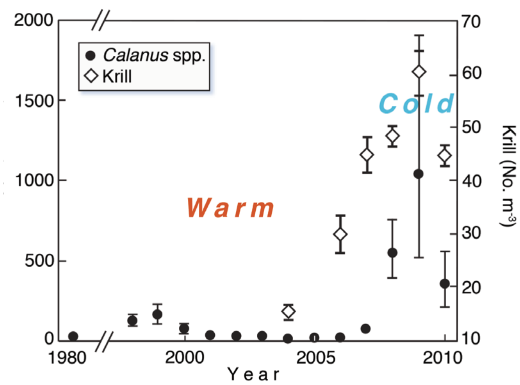
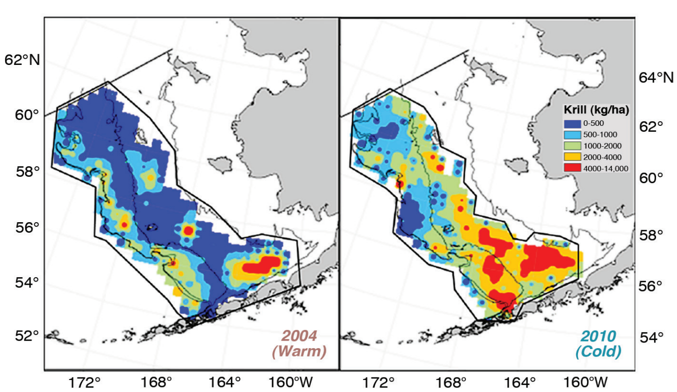
Fig. 1



Associated with a change from warm conditions (2000-2005) to cold conditions (2007-2010) was an increase in the number of Calanus copepods and krill on the eastern Bering Sea shelf. Vertical bars represent the standard deviation of the data.

Fig. 2



In cold years, krill were more abundant and more widely distributed across the shelf compared to warm years as determined by acoustic surveys of krill biomass.

The Big Picture

The Bering Sea shelf supports one of the world's most productive fisheries and accounts for a large fraction of U.S. fisheries landings. This system is highly susceptible to climate change, but our understanding of that susceptibility remains poor. In this study, we addressed several key Bering Sea Project hypotheses, including the influence of climate and ocean processes on food availability for fish and mammals (bottom-up processes), and dynamic ecosystem controls from predation (top-down processes). We examined how the presence or absence of sea ice over the eastern shelf in spring influenced the flow of energy through the pelagic ecosystem in the eastern Bering Sea, particularly the distribution, standing stock, and trophic role of large crustacean zooplankton (LCZ).

IMPACT OF SEA-ICE ON BOTTOM-UP AND TOP-DOWN CONTROLS OF CRUSTACEAN ZOOPLANKTON AND THE MEDIATION OF CARBON AND ENERGY FLOW IN THE EASTERN BERING SEA
A component of the BEST-BSIERP Bering Sea Project, funded by the National Science Foundation and the North Pacific Research Board with in-kind support from participants.

also addressed through integrated models and by expert panels at two interdisciplinary workshops.

We found that the spatial distribution of krill differed between warm and cold years with greater abundance over the shelf during cold periods (Figure 2). This may be the result of changes in ocean circulation as there was more southward flow during cold years that brought ice and colder water over the southern shelf, which in turn excluded some predators from the shelf. However, when using a multivariate regression analysis of predator-prey biomass, it did not appear that Walleye Pollock (*Gadus chalcogrammus*), the major fish predator, exerted top-down control on krill populations (Figure 3).

In spring, phytoplankton and ice algae were the main food source for LCZ, but in summer, phytoplankton were smaller and micro-zooplankton were the major food source for LCZ. Energy flow through the ecosystem appeared to be different in warm and cold conditions (Figure 4). In warm years, the phytoplankton bloom occurred later, and sea ice and ice algal communities were less extensive. In cold years, algae growing on the bottom of the ice, and earlier ice edge blooms, gave the LCZ an early boost of food, helping sustain egg production and survival of juveniles. This may partially explain the return of LCZ during recent cold years.

Why We Did It

Results garnered from these studies will provide a better understanding of regional and temporal (seasonal, interannual) variability in secondary production in the eastern Bering Sea and its ability to support major fisheries. From this study, we hope to develop new mechanistic and conceptual models of carbon and energy flow, and to provide improved predictions of the magnitude and fate of secondary production in an ever-changing Bering Sea.

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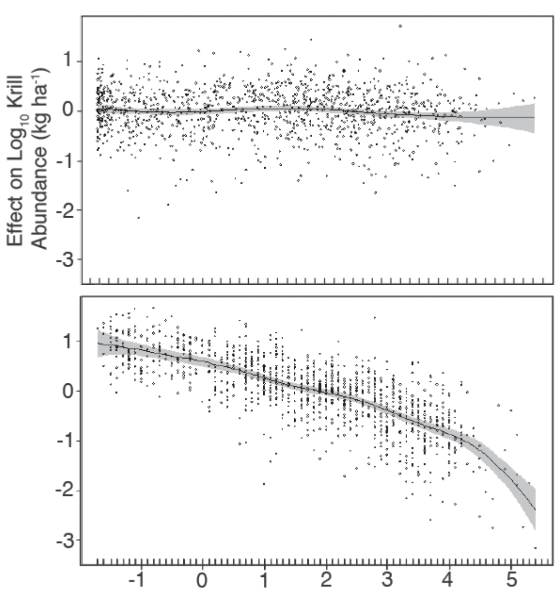
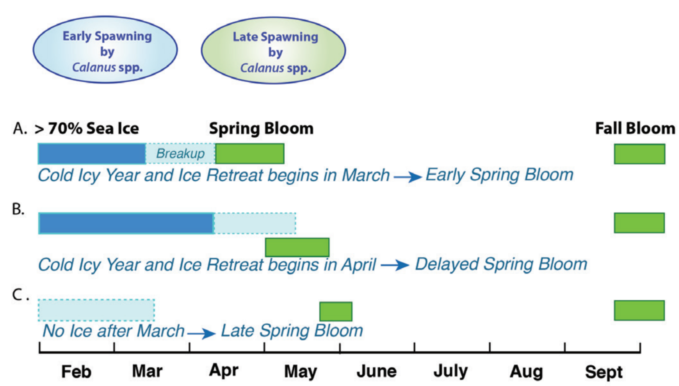
The Bering Sea Project is a partnership between the North Pacific Research Board's Bering Sea Integrated Ecosystem Research Program and the National Science Foundation's Bering Ecosystem Study. **www.nprb.org/beringseaproject**

Fig. 3



Partial effects of pollock biomass and bottom temperature in a multivariate model (GAM) of krill biomass density. Taken together, the flat pollock curve and steep temperature curve suggest that krill abundance is greater at colder temperatures, but is not tightly linked to changes in pollock biomass, casting doubt on top-down control by predation.

Fig. 4



Three scenarios of ice retreat and its influence on the timing of the spring phytoplankton bloom in the southeastern Bering Sea. If sea ice (blue) is present after mid-March (Scenarios A and B), a phytoplankton bloom (green) is present during sea ice retreat. If ice retreat is early (Scenario C), a spring bloom usually occurs in May.

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