BEST-BSIERP Bering Sea PROJECT

UNDERSTANDING ECOSYSTEM PROCESSES IN THE BERING SEA 2007–2013

The Spring Bloom Matters

THE IMPORTANCE OF THE SPRING BLOOM TO THE OVERALL PRODUCTIVITY OF THE BERING SEA

The success of the highly productive Bering Sea fishery depends on massive blooms of tiny, single-celled plants that occur each spring when increasing light and abundant nutrients enable these plants to flourish both in the ice (ice algae) and in the water column (phytoplankton) as the sea ice retreats. These blooms support a zooplankton community that has just awoken from a period of rest during the long, dark, cold winter. This community is made up of the small, unicellular microzooplankton and the larger, multicellular, mostly crustacean mesozooplankton dominated by copepods and krill. The zooplankton community, in response to the spring bloom, dramatically increases its numbers and biomass and provides an abundant, highly nutritious food source for seabirds, mammals and fish. This project seeks to better understand the importance of the spring bloom to the Bering Sea ecosystem and to predict how these blooms might be altered for better or worse in a warmer Bering Sea.

What We Did

We collected samples over a large region of the shelf, using ice cores, water samplers and nets to identify and quantify the biomass of the planktonic ecosystem components. Shipboard experiments measured important biological rates, such as zooplankton feeding, growth and reproductive rates. Datasets then were integrated and synthesized to determine regional patterns and year-to-year variability in the biomass, productivity and consumption rates of different planktonic components. A new planktonic ecosystem model was developed to better understand the food web dynamics and to predict the response of the planktonic ecosystem to future climate changes.

What We Found

We found the spring ice-associated bloom (Figure 1) to be of vital importance to the productivity of the Bering Sea. It begins the plankton growing-season and supplies a large and dependable food source to which the life cycles of many of the important zooplankton, and

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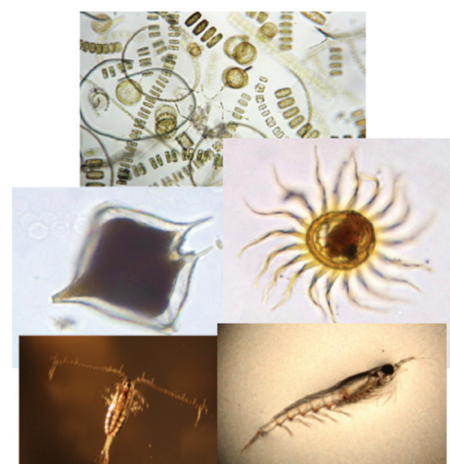
Fig. 1



The Bering Sea planktonic food web in spring (not to scale). (Top) A mixed diatom assemblage from the Bering Sea spring bloom. Diatoms are the dominant component of both ice algal and phytoplankton communities during spring. Photo credit: E. Sherr. (Middle) Dinoflagellates like this Protoperidinium *sp (left) and ciliates similar to the* Leegardiella *sp. (right) are important members of the microzooplankton communities. Photo credit: E. Sherr. (Bottom) The copepod* Calanus glacialis/marshallae *(left) and the euphausiid (krill)* Thysanoessa raschii *(right) are dominant components of the mesozooplankton. Photo credit: C. Gelfman.*

The Big Picture

Using a modeling approach combined with extensive data collection and at-sea experiments, we tackled a conundrum: why do years with warm ocean temperatures result in low overall success of copepods and other large zooplankton, despite better food supplies and faster growth? Copepod overall success is extremely sensitive to winter prey concentrations, even though those concentrations are orders of magnitude lower than those during the spring bloom. Increased mortality during warm years and/or lower growth rates at warm temperatures that exceed the optimal thermal tolerance for the animals also are important. Our model provides almost as many new questions as answers, and can be used to guide future research directions

LINKING SEA-ICE RETREAT TO PLANKTON COMMUNITY STRUCTURE AND FUNCTION IN THE BERING SEA: DATA SYNTHESIS, BIOPHYSICAL MODELING, AND MULTI-DECADAL PROJECTION

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.

benthic, species are timed.

The planktonic food web in the Bering Sea is far more complex than simply large zooplankton feeding on large phytoplankton. Copepods and krill all readily feed on ice algae, phytoplankton and microzooplankton. Frequently microzooplankton, not phytoplankton, are their preferred food.

The life cycles of many important zooplankton species are timed to take advantage of the spring bloom. Peak reproduction of the large copepod *Calanus glacialis/marshallae* coincides with the bloom. Adult females that have survived the food-limited winter are mature and ready to take advantage of the rich bloom food environment. These animals respond rapidly to the increased food supply by producing up to 50 eggs per female per day. The eggs and early developmental stages of copepods are an important food source for larval fish.

The spring bloom provides an almost inexhaustible food supply allowing copepods to increase their biomass by up to 10-fold between early spring and summer. Even so, the zooplankton community leaves much of the spring bloom production un-grazed. This excess productivity falls to the sea floor where it supports a rich benthic community including commercially important crustaceans such as king crab. What if a future warmer ocean upsets this balance? We believe that one reason that the spring bloom is so productive is that it gets a jump on the zooplankton grazers, which are not very abundant after the long winter and cannot consume all of the primary production. A warmer ocean could result in tighter coupling between the planktonic producers and consumers with detrimental consequences for the benthic (sea floor) community.

Our planktonic ecosystem model indicates that large zooplankton have greater success in cold years in spite of, not because of, spring-summer conditions (Figure 2). In warm years, total primary and microzooplankton production are higher and warmer temperatures mean that growth and development of the large zooplankton are faster. Yet the large zooplankton have lower overall success in warm years. A new model of copepod life history tradeoffs is narrowing down the potential reasons for this. One idea is that warm winter temperatures decrease copepods' overwintering success by making them burn through their energy reserves too fast, but the model suggests that this direct temperature effect is outweighed by the positive effect of higher temperatures on spring-summer growth and development. Another idea is that cold years might favor the production of ice algae prior to the spring bloom.

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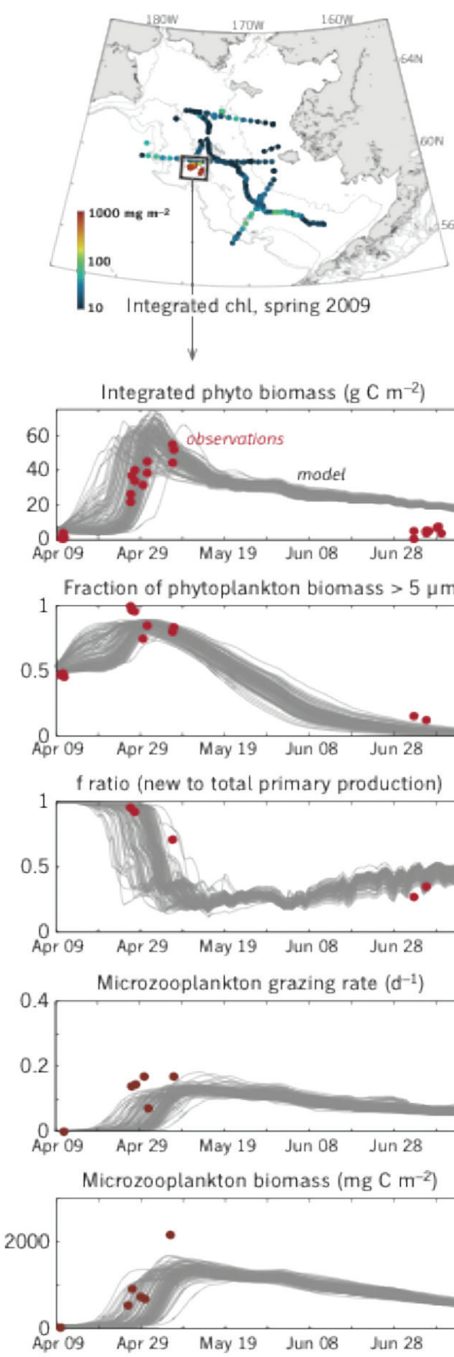
The Bering Sea Project is a partnership between the North Pacific Research Board's Bering Sea Integrated Ecosystem Research Project and the National Science Foundation's Bering Ecosystem Study. **www.nprb.org/beringseaproject**

Fig. 2



Model results. Time evolution of an intense ice-edge bloom, from spring-summer 2009 observations (red) and the model (gray). Gray lines show modeled community evolution along Lagrangian transport pathways that intersect the observed late April bloom; the spread among them shows the effect of small-scale patchiness and variability in ice-retreat timing. Observations are courtesy of the Mordy, Lomas, Sambrotto, and Sherr groups.

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