



BEST-BSIERP *Bering Sea* PROJECT

UNDERSTANDING ECOSYSTEM PROCESSES IN THE BERING SEA 2007–2013

Distributions of Bering Sea Forage Fish

THE MOVING MIDDLE OF THE FOOD WEB

Forage fish, which include capelin, herring, and the young life stages of walleye pollock and Pacific cod, are food for many fish, birds, and mammals in the Bering Sea. These predators are ecologically important, commercially valuable, and the focus of traditional harvest. Evidence suggests that forage fish distributions (vertically within the water column and horizontally across the Bering Sea) can change from year to year, and yet we don't fully understand why. Knowing that climate change may impact the available habitat for forage fish, it is necessary to understand the *where*, *how many*, and *why* of fish distribution to predict how changes may affect forage fish populations and the predators that count on them as prey.

How We Did It

At sea, we used echosounders and trawling to map distributions of forage fish between BASIS (Bering Aleutian Salmon International Survey) survey stations in 2008–2010. The analysis was expanded to include existing acoustic data from 2006–2007. In 2008, age-0 pollock were primarily found in the surface water, less than 35 m deep (Figure 1). In both 2009 and 2010, highest densities were found in dense schools in the midwater, more than 35 m deep (Figure 2). Both age-0 Pacific cod and capelin had high densities in the surface in 2010 as compared to 2009 (Figures 3 and 4), but no or low densities in the midwater. We evaluated the influence of physical,

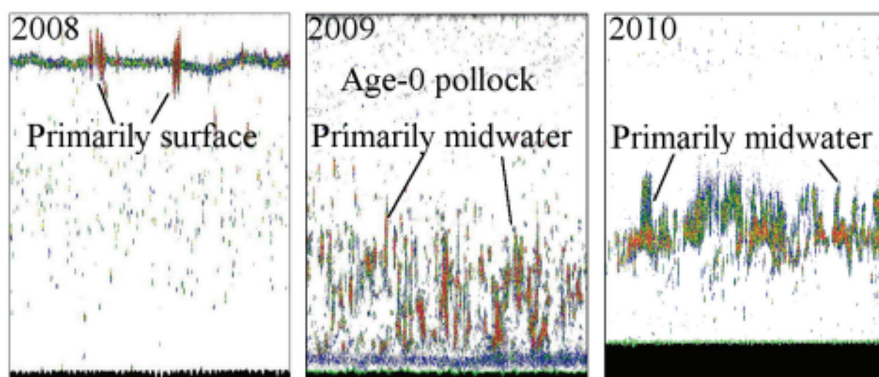
biological, and/or climate factors on forage fish distributions. Models varied by species but, in general, temperature, bottom depth, and/or zooplankton prey were important predictors of forage fish presence and density. Interestingly, annual variables, such as storminess in June and sea ice, were sometimes as or more predictive than local conditions at a station.

Why We Did It

Environmental conditions (e.g., temperature, salinity), the availability of zooplankton prey, and

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Fig. 1



Acoustic echograms showing differences in vertical distribution of age-0 pollock in 2008, 2009, and 2010. Bottom depth shown is ~80 m in 2008, ~110 m in 2009, and ~150 m in 2010.

The Big Picture

Forage fish are the critical middle of aquatic food webs throughout the world. Changes in forage fish densities or distributions can affect forage fish recruitment, nesting/breeding success of birds, and/or movements of fish or marine mammal predators that are important for commercial or traditional harvest. Understanding how forage fish distribute themselves is critical when evaluating potential impacts of climate change, and to fulfill the requirements of ecosystem-based approaches to fisheries management. Our baseline information can inform Bering Sea models that predict biological responses to climate change and improve methodologies for future abundance estimate surveys.

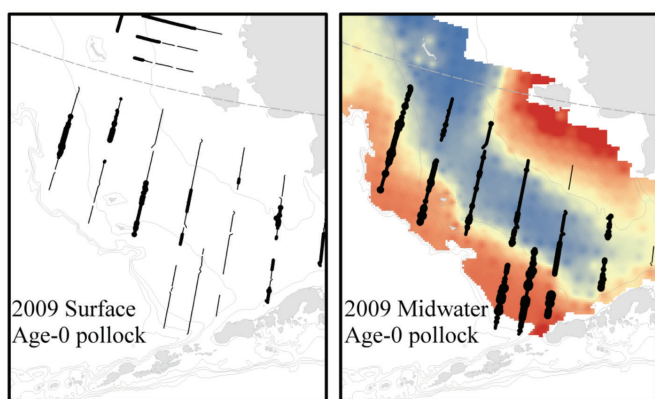
vulnerability to predators can all influence survival of forage fish. Distributions may result from a combination of selection of preferred conditions and the influence of water movement in the Bering Sea. If forage fish vertical or horizontal distributions change with environmental conditions, then food availability for predators

and our ability to obtain information on forage fish distributions from existing surveys will also change. A comprehensive analysis that included physical, biological, and climate factors was needed to understand what affects forage fish distributions.

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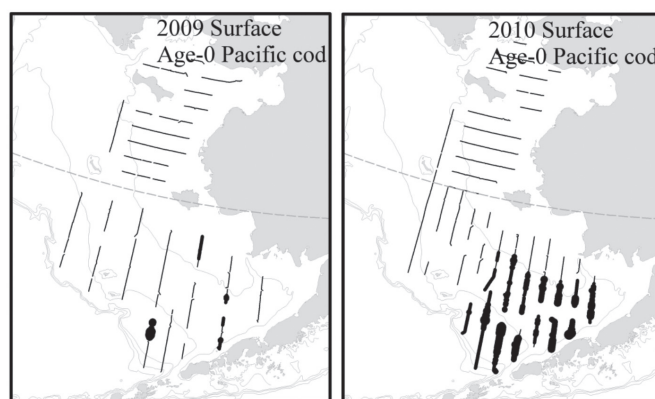
The Bering Sea Project is a partnership between the North Pacific Research Board's Bering Sea Integrated Ecosystem Research Program and the National Science Foundation's Bering Ecosystem Study. www.nprb.org/beringseaproject

Fig. 2



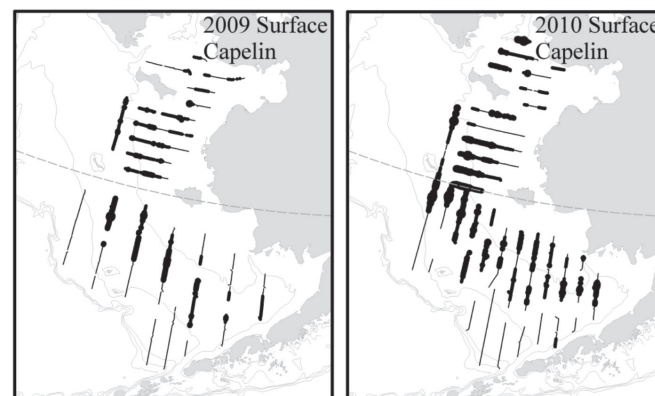
Distribution of age-0 pollock in the surface (left) and midwater (right) in 2009. Larger dots show higher densities. Bottom temperature ($^{\circ}\text{C}$) was an important predictor of midwater pollock density and is shown on the midwater figure (red is warmest). Although there were few age-0 pollock in the surface zone in 2009, there were regions of high densities in the midwater zone. Bottom temperature data courtesy of Bob Lauth (NOAA-AFSC).

Fig. 3



Distribution of age-0 Pacific cod in the surface waters in 2009 (left) and 2010 (right). Larger dots show higher densities. High densities of age-0 Pacific cod were observed in 2010 in regions that had low densities in 2009.

Fig. 4



Distribution of capelin in the surface waters in 2009 (left) and 2010 (right). Larger dots show higher densities. Capelin were found in the same regions in both years, but densities were higher and more continuous along transects in 2010.



Forage fish, flatfish, and jellyfish from a surface trawl catch on the R/V Oscar Dyson in 2010.