Interannual Variability in Physical-Biological Properties on the Shelf near Barrow, Alaska

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The continental shelf near Barrow, Alaska, is an important feeding area for bowhead whales (*Balaena mysticetus*) during their spring and fall migrations between their wintering grounds in the Bering Sea and their summering grounds in the Canadian Arctic (Figure 1). Iñupiaq hunters harvest bowhead whales at Barrow as subsistence food during both the spring and fall migrations and have done so for centuries.

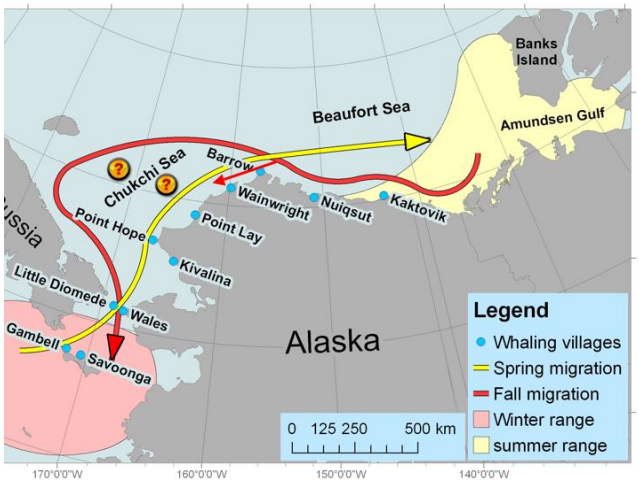

Figure 1: Migration pathways and wintering and summer grounds of the bowhead whale in the Western Arctic. Figure courtesy of Lori Quakenbush, Alaska Department of Fish and Game.

Bowhead whales feed on zooplankton, especially copepods and euphausiids or krill. Copepods and krill are crustaceans that are similar to shrimp but smaller (7 millimeters – 20 millimeters). In the Western Arctic, copepods are found in waters of both Arctic and Pacific origin, while krill are found in water from the Pacific that enters the Western Arctic through the Bering Strait. To feed efficiently, baleen whales, such as the bowhead whale, must feed where high concentrations of their zooplankton prey are found. The recurrence of feeding bowhead whales near Barrow suggested that this region was a favorable feeding environment for the whales; however, the mechanisms that produce this environment were largely unknown.

Relatively few ocean observations of the shelf near Barrow have been made. However, it is known that the oceanographic conditions are complex and that several types of water typical of the Arctic and the Pacific converge at Barrow. The different water types on the shelf determine the kind of the zooplankton prey available to the bowhead whale.

Along with several of my colleagues, I investigated the physical and biological oceanographic conditions on the shelf near Barrow during late summer of 2005 and 2006 as part of a study funded by the National Science Foundation (NSF). Analyzing environmental variability, oceanography, bowhead whale distribution, and the success and resilience of Iñupiat subsistence whaling, our results demonstrated that interannual and shorter term (days-weeks)

variability in ocean conditions was very high. Our first sampling year of 2005 was characterized by little sea ice and very warm water, during which we observed feeding bowhead whales in early September. By contrast, ice cover was much more extensive and water temperatures much colder in 2006, yet feeding bowhead whales were again observed in early September. In both years, short-term variability was intimately tied to changes in wind speed and direction. These wind events also had a profound effect on the whale prey concentrations on the shelf, with high concentrations found following periods of wind from the east. It is evident that both longer (interannual) and shorter (days-weeks) term variability are important in establishing the presence of a favorable feeding environment for the bowhead whale near Barrow. This coastal region is also particularly susceptible to ongoing climate change, both through changes to the ecosystem and through human activities that increase with a more hospitable, less ice-covered ocean, such as commerce, oil exploration and development, and tourism.

Our results were based on only two years of sampling; however, to better understand longer term and interannual variability in the environment, sustained sampling over multiple years must occur. We were fortunate to obtain funding from WHOI's Arctic Research Initiative (ARI) to continue our sampling in 2007. We used the ARI funds to leverage additional funding from the University of Alaska Coastal Marine Institute, which allowed colleagues from the University of Rhode Island and the University of Alaska, Fairbanks, to continue participating in this research. In addition, because the National Oceanic and Atmospheric Administration (NOAA) and the Minerals Management Service (MMS) were interested in conducting sampling in this region at that time, we were able to augment our ARI funding with support from them. This new project now includes studies of whale behavior using whale tagging, conducted by colleague Mark Baumgartner, Assistant Scientist in WHOI's Biology Department.

We used the *43' R/V Annika Marie* for our work in Barrow from August 16 to September 11, 2007. Because the *Annika Marie* is small in size, we were limited by weather and could not work when sustained winds exceeded 20 knots. During our time in Barrow, we were able to work at sea for 13 days and were weathered-out for 16 days. Overall, the oceanographic sampling was highly successful despite the poor weather. Sixty-four stations were conducted, including many with multiple types of collections and instrument deployments (Figure 2). We sampled temperature, salinity, chlorophyll, and current direction and velocity using two towed instruments. We also collected samples to determine the numbers of plankton (whale prey) and nutrients (Figure 3, next page). Before leaving Barrow, I attended the Barrow Whaling Captains Association meeting to present the results of our work, because our project has been supported by the Barrow whaling captains since its inception in 2005. Coincidentally, 2007 was an

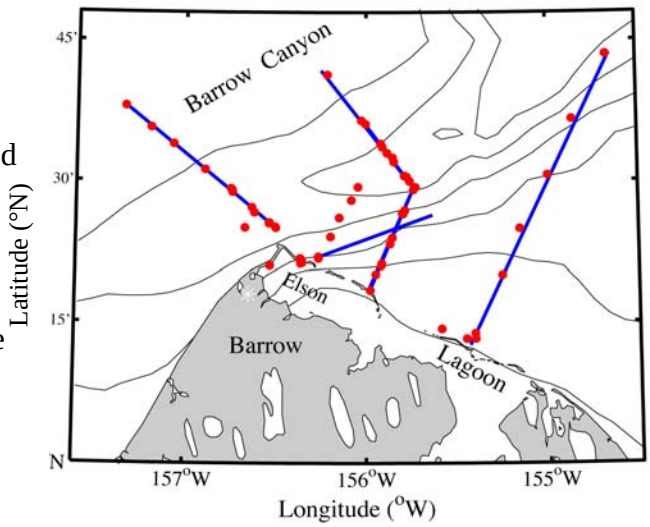

Figure 2: Locations of sampling in 2007. Red dots indicate where net tows to collect whale prey were conducted. Blue lines indicate transects along which we towed instruments.

extremely important year to be sampling in the Arctic Ocean, because the least summer ice extent on record occurred. We encountered no sea ice at all, and we measured extremely high water temperatures (almost 12°C) (Figure 3).

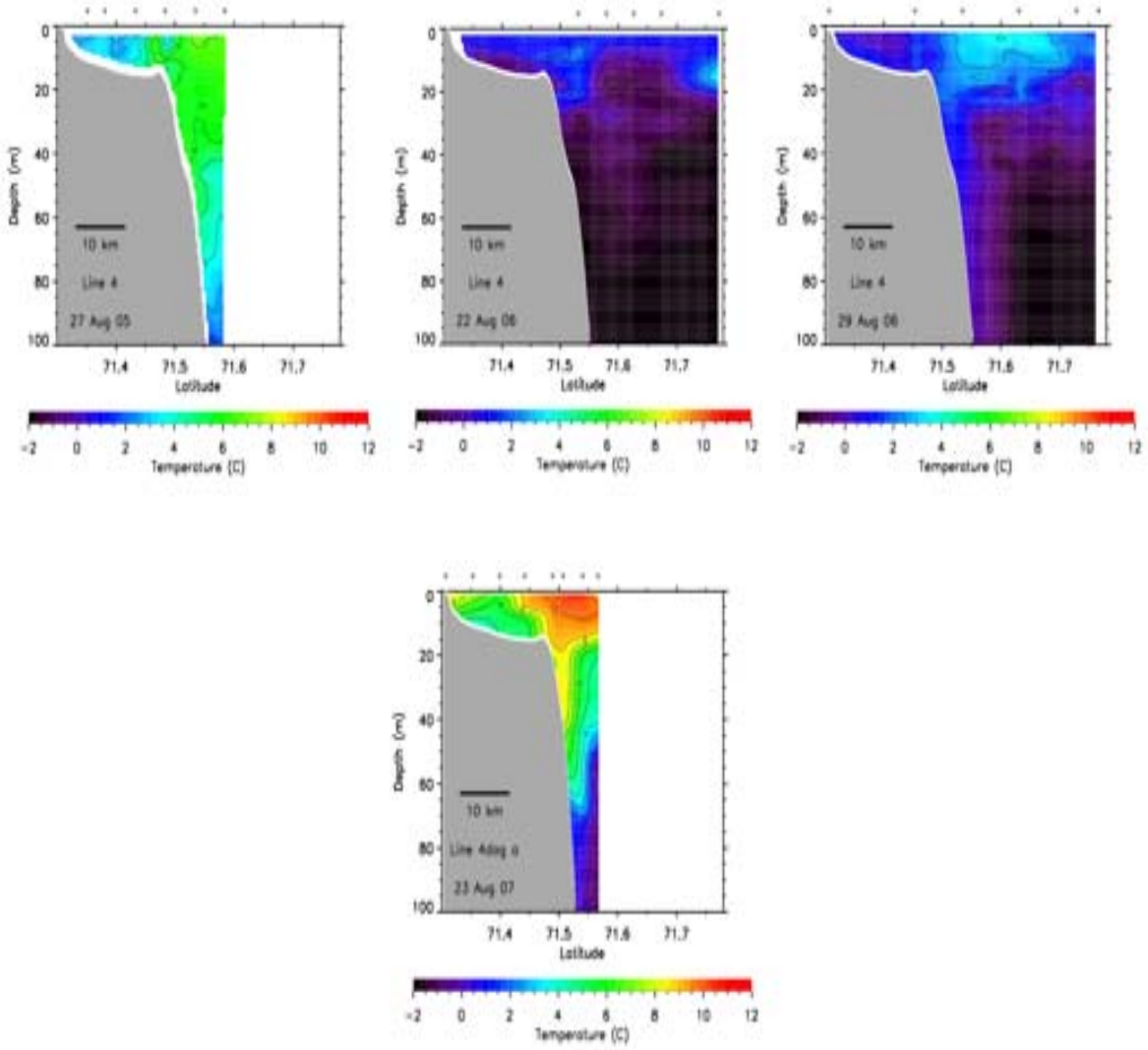

Figure 3: Temperature sections across Barrow Canyon from 2005 (top left), two dates in 2006 (top center and right panels), and 2007 (lower panel). Note extremely high temperatures in 2007 and marked difference in temperature between the 2006 panels, separated only by a few days.

Our work in the Barrow region continues, supported by funding from NOAA/MMS and from the National Oceanographic Partnership Program (NOPP). We now believe that a combination of wind and currents brings bowhead prey onto the shelf to the Northeast of Barrow and concentrates it there, making it sufficiently dense for the bowhead whales to feed (Appendix, next page). Support from the Arctic Research Initiative contributed substantially to the success of the project and to the establishment of what will soon be a five-year record of ocean conditions on the shelf near Barrow.

Appendix: Mechanism Producing Bowhead Whale Feeding Hotspot Near Barrow.