Environmental Variability, Bowhead Whale Distributions, and Iñupiat Subsistence Whaling Near Barrow, AK

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On-Going Project

• 2005 & 2006: National Science Foundation, Study of the Northern Alaska Coastal System (SNACS)
• 2007: WHOI Arctic Initiative, UAF Coastal Marine Institute, U.S. NOAA/National Marine Mammal Laboratory/Minerals Management Service
• 2008 & 2009: NOAA/NMML/MMS, NOPP (National Oceanographic Partnership Program)
Bowhead Whale Migration

- Bowhead whales are recurrently found feeding near Barrow, AK during their fall migration from the Canadian Arctic to the Bering Sea. Bowhead whales are hunted near Barrow by the Iñupiat and have been so for centuries.

Map Courtesy Lori Quakenbush
GOALS OF OUR RESEARCH

• Develop a mechanistic understanding of the biological and physical ocean processes that lead to the formation of a favorable feeding environment for the bowhead whale near Barrow AK during their fall migration from the Canadian Arctic to the Bering Sea

• Understand how climate variability might change the locations of good feeding spots when the whales are near Barrow

• Understand how these changes may impact whaling success and hence the whaling tradition

• In addition, the sustained annual sampling also has provided us with an unprecedented record of the inter-annual variability in ocean conditions at this critical location during a period of ongoing climate and environmental change
We used a combination of oceanographic and aerial field sampling, biological and physical modeling, retrospective data analysis, and interviews with local hunters to address these questions.
Field Sampling during 2005 - 2009

- Aerial surveys to document distributions of bowhead whales in late August - early September 2005 & 2006
- Oceanographic sampling using the 43’ R/V Annika Marie from mid-August to mid-September 2005-2009
- Bowhead whale stomach contents sampled in 2005 & 2006
Analysis of harvested bowhead whale stomach contents shows that the whales feed on both copepods (found in both the Arctic and Pacific) and on euphausiids or krill which are believed to be native to the Bering Sea (or Pacific) but are eaten by the whales harvested near Barrow.

- Krill may not reproduce in the Arctic and hence must be reintroduced annually.
- Because the prey is very small, and whales are very large, the whales need very dense concentrations of prey for feeding to be efficient and worthwhile.
Where do krill near Barrow come from?

- 24% of the krill in the surface water and and 94.6% of the krill in the bottom water reach Barrow.
- Krill entering the Chukchi Sea in spring can easily make to to Barrow by fall, coinciding with the arrival of the whales.
- Note: Krill are adjacent to but not ON the shelf near Barrow.

Locations of Whales Near Barrow

- Most whales seen on shelf to NE of Barrow in both interview reports and aerial surveys
- 88% of whale strikes (dots) occurred on the shelf to the NE of Barrow

Ashjian et al., in press, Arctic June 2010
Formation of “Krill Trap”

- During periods of winds from the east, krill upwell along the Beaufort Shelf but are diffuse on the shelf. Water escapes around Pt. Barrow to the SW.
- During periods of wind from the S, SW, or W or weak winds, the ACC is strong and close to the eastern side of Barrow Canyon, trapping water on the shelf and concentrating krill.

Ashjian et al., in press, Arctic June 2010
Upper Water Column Velocity

- Winds from E or NE: ACC offshelf and water escaping shelf around Pt. Barrow
- Winds from S or W or weak winds: ACC close to shelf, not water escaping
Periods of Upwelling and When the Krill Trap is “Active”

Winds at Barrow

<table>
<thead>
<tr>
<th>Year</th>
<th>Upwelling</th>
<th>Trap Active</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>14</td>
<td>8</td>
</tr>
<tr>
<td>2006</td>
<td>9</td>
<td>12</td>
</tr>
<tr>
<td>2007</td>
<td>22</td>
<td>10</td>
</tr>
<tr>
<td>2008</td>
<td>14</td>
<td>10</td>
</tr>
<tr>
<td>2009</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

• More days of upwelling favorable winds in 2007; many days of winds from the east. *C. hyperboreus* on the beaches of Prudhoe.
• Number of days when “trap” is active are about the same in all years (8-12)

Blue=Upwelling; Red=Trap Active
★ Bowhead Whales Observed
Abundance of Juvenile and Adult Euphausiids/Krill on the Shelf

- Abundances of krill greater on shelf when “krill trap” is active
- Greatest abundances in 2007 when the most upwelling days occurred
- Krill can be found inshore as shallow as 5 m or less
Whale Group Size and Winds

- Whale observations from aerial surveys conducted from 1984-2004 during the Bowhead Whale Aerial Survey Project (BWASP)

- Mean size of whale groups was larger (p<0.001) when winds were from the S (krill trap active)

- Mean size of whale groups was larger (p<0.001) when winds 2-3 days prior to each survey was from the SE (upwelling ongoing)

Ashjian et al., in press, Arctic June 2010
Whale Stomach Contents

- Half of the whales harvested on shelf (z<50 m) contained euphausiids

Moore et al., in press, Arctic June 2010
Interannual Variability

Ocean Temperature across the Beaufort Shelf and in Barrow Canyon: 2005-2009

Coccoid Cyanobacteria: 2002-2009

- Three “warm” years when Pacific Water Temperature > 4°C
- 2007 was particularly warm
- Two “cold” years (2006 & 2008)
- Sea ice present only during cold years
- Coccoid cyanobacteria present in any abundance only in water of >4°C
- Coccoid cyanobacteria are an indicator of warm Pacific Water
- Note: Inclusion of data from 2002 and 2004 (SBI program)
What is driving differences in PW temperature and biology near Barrow?

Winsor & Chapman (2004) model indicates greater transport through Barrow Canyon when regional winds are from the S-W quadrant and least when winds are from the N-E quadrant.

Situation 1: Geostrophic winds from S or W. Years with warm PW, little ice near Barrow.

Maps from NOAA/ESRL.
Summary of Some Interannual Differences

<table>
<thead>
<tr>
<th>Year</th>
<th>Ice South of 71°N</th>
<th>Geostrophic Winds</th>
<th>PW&gt;4°C</th>
<th>Syn</th>
<th>Water Temp at Nome &amp; Red Dog Mine</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>Yes</td>
<td>W to E</td>
<td>No</td>
<td>No</td>
<td>11.2/no data JUL</td>
</tr>
<tr>
<td>2003</td>
<td>Yes</td>
<td>W to E</td>
<td>Yes</td>
<td></td>
<td>11.7/no data JUL</td>
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<tr>
<td>2004</td>
<td>No</td>
<td>S to N</td>
<td>Yes</td>
<td>Yes</td>
<td>14.2/no data JUL</td>
</tr>
<tr>
<td>2005</td>
<td>No</td>
<td>S to N</td>
<td>Yes</td>
<td>Yes</td>
<td>12.2/13.3 AUG</td>
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<tr>
<td>2006</td>
<td>Yes</td>
<td>N to S</td>
<td>No</td>
<td>No</td>
<td>11.3/8.6 AUG</td>
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<tr>
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<td>No</td>
<td>S to N</td>
<td>Yes</td>
<td></td>
<td>14.6/14.2 AUG</td>
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<tr>
<td>2008</td>
<td>Yes</td>
<td>N to S</td>
<td>No</td>
<td>No</td>
<td>no data/8.9 AUG</td>
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<tr>
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<td>S to N</td>
<td>Yes</td>
<td>Yes</td>
<td>11.9/9.7 AUG</td>
</tr>
</tbody>
</table>

- Years with geostrophic winds that result in lower transport of water from the Pacific (2006, 2008) are generally those with more ice, colder Pacific Water, and no cyanobacteria.
- Years with geostrophic winds that result in high transport of water from the Pacific (2003, 2004-2006, 2007, 2009) are generally those with low ice, warm Pacific water, and the presence of cyanobacteria.
- Temperatures at Red Dog Mine are cooler in 2006 and 2008, consistent with the cool PW seen near Barrow, and indicates that these differences are regional.
Summary

- The shelf to the NE of Barrow is a recurrent feeding area for bowhead whales during their fall migration. They are usually seen on the shelf and most of the strikes during whaling occurs in this region.
- We identified a physical mechanism that produces a favorable feeding environment (high abundances of krill prey) for the whales on the shelf near Barrow. Whales captured here often have been feeding on krill.
- Interannual variability in the physical and biological environment is driven by regional differences in the mean geostrophic winds.
- Interannual variability of the physical environment in this region is considerable yet the “krill trap” mechanism operated under all observed conditions and whales feed, and are harvested, on the shelf near Barrow persistently despite this variability.
- Barrow is able to meet its quota of whales every year because the window of opportunity (good weather, whales present) has been sufficiently long each year. Iñupiat whaling success to date is resilient to ongoing environmental change.
- Future environmental and anthropogenic change, including increased periods of bad weather, changes in whale prey availability near Barrow, and changes in whale migration routes in response to changes in prey availability and anthropogenic noise, could negatively impact Iñupiat whaling success.
Acknowledgments

• Phil Alatalo and Aaron Hartz for field sampling and data analysis
• Elizabeth Spears, Stephanie Schively, and Iris Prophet for interviews with Barrow whalers and compilation of interview data
• Dan Torres for ADCP data processing and Joe Jennings for nutrient analysis
• Bill Kopplin, Ned Manning, Mike Johnson, and Randy Pollock, the captains of the R/V Annika Marie, for their valuable inputs to our program
• Ralph Aiken piloted the 2005 aerial surveys
• Charles Monnett (MMS) for providing aircraft support and collaborating on the 2006 aerial survey
• The Barrow Whaling Captains Association, particularly Eugene Brower, the Alaska Eskimo Whaling Commission, the North Slope Borough, and the community of Barrow for their support
• Glenn Sheehan and the Barrow Arctic Science Consortium Staff for logistic support in Barrow
• VECO/CH2MHill Polar Services for logistic support in Deadhorse / Prudhoe Bay
• Bill Streever, Wilson Cullers, and Tatyana Venegas at British Petroleum for assistance in accessing West Dock in Prudhoe Bay to load the Annika Marie
• The ARMADA Program at the University of Rhode Island for the participation of Jeff Manker and Kirk Beckendorf (high school teachers)
• Funded by the National Science Foundation (SNACS), the University of Alaska Coastal Marine Institute, the Woods Hole Oceanographic Institution Arctic Initiative, the NOAA National Marine Mammal Laboratory and Minerals Management Service, and the National Oceanographic Partnership Program