Climate Change and Baleen Whale Trophic Cascades in West Greenland

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LONG-TERM GOALS

The primary goals of this study have been to examine and contrast the foraging strategies of two baleen whale species in West Greenland. We used a multidisciplinary approach by combining observations of movements, foraging ecology and phenology collected by satellite and archival telemetry with intensive and localized *in situ* sampling of ocean conditions and prey availability. These baseline trophic relationships are quantified using spatial movement and bioenergetic models.

OBJECTIVES

We are focusing on two species in Disko Bay, West Greenland and asking the following questions: 1) "What is the spatial and temporal overlap between bowhead whales, phytoplankton, and zooplankton after the spring sea ice breakup in April and May?", and 2) "What is the spatial and temporal overlap between humpback whales and capelin in June and July, and 3) on what space and time scales do these two large whales overlap?". Answering these questions will enable us to determine the spatial, temporal, and ecological overlap between these two top predators in West Greenland. Fluxes of organisms across ecosystem boundaries have major consequences for community dynamics and predation can create strong effects throughout food webs. This is one of the few Arctic studies conducted on the multi-species trophic coupling between whales and their prey. The simplicity of the food chains in West Greenland offer unique opportunities to gain insight into predator-prey dynamics also relevant to more complex ecosystems.

APPROACH

This portion of the study focused on the foraging ecology of bowhead whales in late-spring just after sea ice break-up. Annual sea ice conditions, including ice concentrations, timing of break-up and locations of the ice edge, are assessed using remotely sensed imagery (MODIS, SMMR/SSMI) (See Laidre and Heide-Jørgensen 2004). Satellite-linked tags are deployed on bowhead whales to determine small-scale movements in Disko Bay, the timing of departure and movements during spring and summer. These tags are simple location-only transmitters as well as binned-dive data transmitters (SPOT5, MK10 and SPLASH tags, Wildlife Computers) with a longevity of 6-12 months that enable detection of feeding areas in the high Arctic. Bowhead whales are also instrumented with high resolution retrievable GPS-based Argos data collection transmitters. The GPS tags receive signals from GPS satellites and acquire and process a small time-stamped snapshot of GPS constellation signals (4-16 msec) to obtain the satellite data needed for location calculation by an extremely fast acquisition processor (<40 msec acquisition time) during each surfacing. These data are transmitted through the Argos Data Collection and Location System. The calculation of GPS positions allows for location accuracy of +/- 55 meters (95%) where the whale was surfacing. The satellite transmitter also provides its own Argos based Doppler shift position as well as data on the diving. Collected data include dive depth, duration of dives, and time-at-depth sampled in 1 hour intervals.

These data are coupled to epibenthic zooplankton data to quantify the spatial and temporal variability in Disko Bay. Near-bottom zooplankton concentrations are investigated at 25 stations where bowhead whales feed. Data are collected with an epibenthic sled and WP2 plankton net, and the zooplankton biomass is determined by simple measurements of volumetric displacement. Further quantification of epibenthic zooplankton abundance is conducted by use of a 200 KHz submersible split-beam echo sounder, which estimates vertical gradients in zooplankton concentrations as well as patchiness between stations.

The portion of the study focused on the foraging ecology of humpback whales utilizes satellite telemetry deployed on whales in spring when they arrive en route from the Caribbean to their feeding areas. The focus is on obtaining a large sample size of tagged whales so that spatial movement patterns and focal areas can be robustly calculated. Movement data are used to describe movement patterns and use of focal areas along the coast using probabilistic spatial techniques, including the time individuals spend feeding in each site and the phenology of the use of the focal areas. These data are related to long-term physical and biological monitoring program in Nuuk Fjord and on the coast of West Greenland, where long-term fishery data are collected to quantify seasonal and inter-annual variations in the biological and geophysical properties of the marine ecosystem.

WORK COMPLETED

Whale field work. All field work was completed between 2008 and 2010 and we are in the analysis phase of the program, operating under a no-cost extention until December 31, 2011. See results below for analysis work.

Zooplankton field work. Zooplanton field work was completed in 2008 and 2009. Analysis was initiated in 2010 and continued in 2011 to elucidate the geographical and vertical distribution of

pelagic food items for bowhead whales where they concentrate in Laksebugten off Qeqertarsuaq/ Godhavn at the southern tip of Disko Island.

RESULTS

Our primary accomplishment for the fourth year of the project was publication of several important manuscripts and continued data analysis. The first publication is Heide-Jørgensen et al. (2011) in *Biology Letters*. This manuscript presents the first observations of distribution overlap of bowhead whales from the two oceans in the Northwest Passage, demonstrating this route is already connecting whales from two populations that have been assumed to be separated by sea ice. Previous satellite tracking has demonstrated that bowhead whales from West Greenland and Alaska enter the ice-infested channels of the Canadian High Arctic during summer (tracking in 2002 and 2003). However in August 2010, two bowhead whales (one tagged in Disko Bay, West Greenland in this study) and one tagged in Alaska entered the Northwest Passage from opposite directions and spent approximately 10 days in the same area, documenting overlap between the two populations.

The second publication is Heide-Jørgensen et al. (2010) in *Endangered Species Research*. Data from skin biopsy samples from 806 bowhead whales collected between 1995 and 2010 at four locations in Nunavut, Canada, (Foxe Basin, Pelly Bay, Repulse Bay and Cumberland Sound) and at one locality in West Greenland (Disko Bay) were used for determination of sex and sexual segregation of bowhead whales in the Baffin Bay stock. This included genetic samples collected during this NOPP program from 2008-2010 (n=61, 69, and 89, respectively) and a manuscript was submitted and accepted for publication. There was a significant dominance of females in the Disko Bay samples (78%) whereas the sex ratio in aggregations at other locations in Nunavut was not significantly different from 50:50. On a broader scale, Baffin Bay is more widely used by adult males and resting or pregnant females from Disko Bat while Prince Regent, Gulf of Boothia, Foxe Basin and north-western Hudson Bay animals are all areas used by nursing females, calves and sub-adults.

The third publication is Wiig et al. (2011) in *Endangered Species Research*. In this paper, we used multi-locus genotype and sex to identify individual bowhead whales from 710 samples collected between 1995 and 2010 at 4 localities in eastern Canada (Foxe Basin, Pelly Bay, Repulse Bay, and Cumberland Sound) and at 1 locality in West Greenland (Disko Bay). In total, 29 recaptures of the same individuals were identified between years, of which 26 individuals were recaptured within the same locality. The remaining 3 were recaptured between sampling localities, from 2 putative International Whaling Commission (IWC) stocks: the Hudson Bay−Foxe Basin stock and the Baffin Bay−Davis Strait stock. These recaptures agree with satellite tracking results that demonstrate movement between IWC stocks and question whether these stocks are true biological entities. The intervals between capture and recapture of females in Disko Bay ranged from 1 to 8 yr. The observed number of multi-year recaptures compared to the expected numbers of recaptures did not indicate any clear cyclicity in the use of Disko Bay consistent with the notion that the migration pattern of females to this area might be tied to their reproductive cycles. A mark−recapture estimate of whales identified in 2010 compared to all dentifications between 2000 and 2009 resulted in an estimate of 1410 bowhead whales (SE = 320, 95% CI: 783−2038) constituting the spring aggregation in Disko Bay. The estimate for the female portion of the aggregation was 999 individuals (SE = 231, 95% CI: 546−1452).

Furthermore, we continue analysis of genetic, movement and dive data in 2011. We anticipate submission of a manuscript to *ICES Journal of Marine Science* special issue on Arctic and sub-Arctic ecosystems in early October (Laidre and Heide-Jørgensen, In Prep). We also anticipate submission of another manuscript on genetics (Bachmann et al. In Prep) in late 2011 to *Endangered Species Research*. Finally we continue developing bioenergetic predation models based on the detailed dive data collected from GPS tags. We are writing programs to identify U-shaped feeding dives and measuring the proportion of time spent on the bottom of each time together with velocity. We also continue an analysis of zooplankton in 2011 and have a draft manuscript has that describes species diversity, densities and biomass found in Disko Bay.

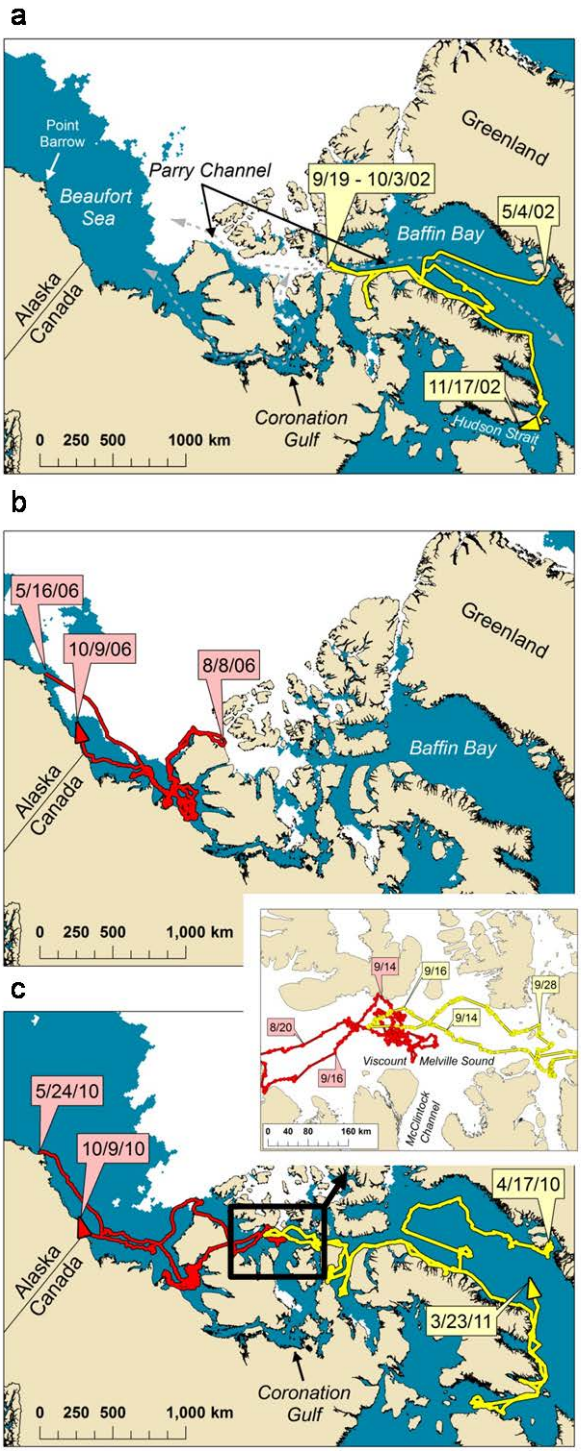

Figure 1. Map from Heide-Jørgensen et al. (2011). The Northwest Passage with tracks of four bowhead whales and extent of sea ice with greater than 50% concentration (white fields). (a) Track of a whale tagged on 4 May 2002 in West Greenland and ice extent on 20 September 2002. (b) Track of a whale tagged in Alaska on 12 May 2006 and sea ice extent on 8 August 2006. (c) Track of a whale tagged on 24 May 2010 in Alaska, one tagged on 15 April 2010 in West Greenland, and sea ice extent on 14 September 2010.

IMPACT/APPLICATIONS

1. A new perspective on the interaction between sub-Arctic and Arctic baleen whales in West Greenland. Few studies have been conducted on the trophic coupling between whales and their prey, given the dynamic nature of the marine environment and the difficulty in observing or quantifying feeding behavior. By instrumenting individual bowhead and humpback whales in a defined region of West Greenland, we are enabled to examine the movements and space use patterns of each species, together with how the two species overlap in space and time and compete for resources.

Potential future impact for Science and/or Systems Applications

2. New techniques for ecological studies of large whales using telemetry. Our study develops technical and methodological advances which are of broad interest for applications in other regions for whale tagging. We have developed a retrievable archival instrument that can be reliably deployed on a large whale and retrieved up to one month later, providing high resolution GPS location data together with dive data measured on a one-second temporal scale. Furthermore, design and deployment of satellite transmitters for large whales is continually being refined based on field efforts during this project to improve attachment. Our technology enabled tracking of 2 baleen whales for >14 months.

3. New bioenergetic models for bowhead whales. Our study develops new bioenergetic models for bowhead whales which can be previously compared to that reported in Laidre et al. (2007) and other studies. Archival dive data are being summarized and used together characterize dives and determine the proportion of whale dives that are feeding dives (i.e. U-shaped dives reaching the bottom) and how much time whales spend at different depths. Combining this information, with data on the amount of water filtered by a whale and known area use and temporal extent of occurrence will improve bioenergetic prediction of the food consumption and competition.

RELATED PROJECTS

None.

PUBLICATIONS

Heide-Jørgensen, M.P., K. L. Laidre, Ø. Wiig, L. Postma, L. Dueck, L. Bachmann. 2010. Large scale sexual segregation of bowhead whales. Endangered Species Research 13:73-78. [published, refereed]

Wiig, Ø, Bachmann, L., Heide-Jørgensen, M.P., C. Lindquist, Laidre, K.L., Postma, L, Dueck, L. Palsbøll, P, and L. Bachmann. 2011. Recaptures of genotyped bowhead whales (*Balaena mysticetus*) in Eastern Canada and West Greenland. Endangered Species Research 14: 235-242. [published, refereed]

Heide-Jørgensen M. P., **K.L. Laidre**, L. T. Quakenbush, and J. Citta. 2011. Northwest Passage opens for bowhead whales. Biology Letters. doi:10.1098/rsbl.2011.0731. [published, refereed]

AWARDS

Laidre K. L. Spoken Presentation: Climate change and baleen whale trophic cascades in Greenland Award: Honorable mention for Best Spoken Presentation by Young Scientist. Ecosystem Studies of Sub-Arctic Seas (ESSAS) Open Science Meeting, Seattle, WA May 22-26, 2011, Comparative Studies of Polar and Sub-Polar Ecosystems.