Climate change and baleen whale trophic cascades in Greenland

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LONG-TERM GOALS

The primary goal of this study is to examine and contrast the foraging strategies of two baleen whale species in West Greenland. We use 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 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 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 longevity of 6-12 months that enable

detection of alternative 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 work. Field work was conducted on Disko Island, West Greenland between 23 April and 12 June 2009 based at Arctic Station (University of Copenhagen research station) in the town of Qeqertarsuaq. 30 bowhead whales and 14 humpback whales were instrumented with satellite transmitters (SPOT5, MK10 and SPLASH, Wildlife Computers, Redmond WA) using a modified pneumatic line Air Gun or a fiberglass pole (See Deployment Sheets for details). Of these, 13 SPOT5s were deployed on bowhead whales and 2 SPOT5s on humpback whales, 8 MK10s were deployed on bowhead whales and 12 MK10s on humpback whales, and 9 SPLASH SWINGs were deployed on bowheads and none on humpbacks. All tags were deployed within 30 nmi of the town of Qeqertarsuaq. Instrumented bowhead whales ranged between 12 m and 17 m in length. Instrumented humpback whales ranged between 10 m and 14 m in length. Several instrumented whales were re-sighted in the vicinity of Qeqertarsuaq during the field season and tags looked to be placed well and there was no indication of phsiological rejection at the taggig site (no swelling or wound). Three bowhead whales were instrumented with GPS archival dive and temperature recording tag using a fiberglass pole collecting detailed dive data and high resolution positions for 1-3 days for each tag. Sixty-nine skin biopsies were collected by biologists and hunters using crossbows from bowhead whales and 11 biopsies from humpbacks. Biopsies were collected immediately after a whale was tagged whenever possible. Biopsies were added to a database of samples from West Greenland (compiled since 2000) and were spilt into two to three pieces for sex determination and genetic analysis with colleagues in Greenland, Oslo and Sweden.

Zooplankton work. The continuation of plankton sampling in 2009 was intended to further 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. Sampling was conducted using the ship RV Porsild, (Arctic Station's research vessel) using two techniques 1) an epibenthic sledge catching pelagic and semi-pelagic zooplankton > 0.5 mm between the surface and 25 - 40 cm above the bottom and 2) with a WP2 plankton closing-net towed vertically sampling various depths from ~3 m above the bottom to the surface. Zooplankton samples were examined in the laboratory of Arctic Station: species from each station were counted, identified to the lowest taxonomic order, and weighed. Samples were sent to Copenhagen for further analysis. In 2009 plankton concentrations were also located with high frequency echo-sounders making selective sampling possible. The plankton was mostly found concentrated in the upper 15 m and in one or two 10 – 40 m thick layers 60 to 120 m depth. Although the echo-sounder recorded larger animals (i.e. shrimp, krill and small fish in the deep layers) the plankton net only caught small planktonic animals and no shrimp and small fish.

RESULTS

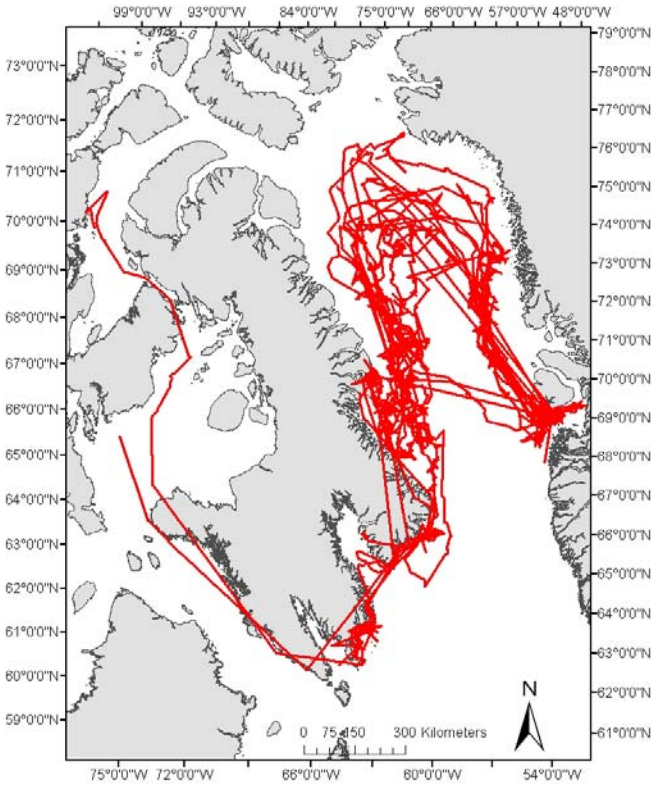

Figure 1. Map of tracklines of 30 bowhead whales instrumented in Disko Bay, 2009. Data are current through August 30.

Our primary accomplishment for the second year of the project was the instrumentation of 44 whales with satellite tags between April and June in Disko Bay (Fig. 1), based on two field seasons, with three additional whale instrumented with a GPS dive tag that collected daily data for one month. Based on the satellite tracking data we found a clear spatial overlap during a several week period of bowhead and humpback whales in Disko Bay during the last half of May and early June. Whales explore several focal areas in the bay and during the period of temporal overlap, there is a clear spatial partitioning of the bay, with bowheads in northern coastal areas and humpback in southern coastal areas. Models are being developed quantifying this overlap. Furthermore, we have begun the initial stages of developing bioenergetic predation models based on the detailed dive data collected from GPS tags. The first step involves identifying U-shaped feeding dives and measuring the proportion of time spent on the bottom of each time together with velocity. We have identified over 13,000 U-shaped feeding dives on detailed dive data (combining all instruments deployed since 2002). Finally, information on zooplankton is being compiled into a manuscript that describes species diversity, densities and biomass found in Disko Bay. The plankton sampled in 2009 was mostly found concentrated in the upper 15 m of the water column and in one or two 10 – 40 m thick layers between 60 to 120 m depths.

Figure 2. A bowhead whale in Disko Bay, West Greenland, May 2009, being instrumented with a satellite transmitter. Photo by Kristin L. Laidre.

IMPACT AND APPLICATIONS

Quality of Life

A new perspective on the interaction between sub-Arctic and Arctic baleen whales in the West Greenland ecosystem. 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 forty-four 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.

Science Education and Communication

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.

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

Laidre, K. L., P. Heagerty, M. P. Heide-Jørgensen, L. Witting, and M. Simon. **2009**. Sexual segregation of common minke whales (Balaenoptera acutorostrata) and sex ratio of catches in Greenland. ICES J of Marine Science [In Press, refereed]

Heide-Jørgensen M. P., K. L. Laidre, M.J. Simon, D. Borchers, and H. Stern. **2009**. The effect of sea ice loss on beluga whales (Delphinapterus leucas) in West Greenland. Polar Research [In Press, refereed]

Gurarie, E., R. Andrews, and K. L. Laidre. **2009**. A novel method for identifying behavioral changes in animal movement data. Ecology Letters 12(5):395-408. [published, refereed]