Can Stable Isotopes Ratios Identify Feeding Events in Bowhead Whales?

Lara Horstmann-Dehn[1], Craig George[2], Gay Sheffield[3]

[1] School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, [2] Department of Wildlife Management, North Slope Borough, [3] Marine Advisory Program, University of Alaska Fairbanks

Introduction

Bowheads (*Balaena mysticetus*) are endangered baleen whales adapted to life in the Arctic Ocean. They are culturally and nutritionally important to the Inuit peoples of Alaska and several circumpolar countries.

Bowheads mainly feed on zooplankton, i.e., copepods and euphausiids (Lowry et al. 2004), although density and abundance of krill patches is largely dependent on weather patterns and ocean conditions (Ashjian et al. 2010). Prey density is important to filter feeding cetaceans to maintain energy balance, yet little is known about bowhead whale metabolic demands, feeding rates, and gut passage.

We have previously shown that bowhead whale digestive efficiency is between 45 and 55%, regardless of the type of prey digested, e.g., euphausiid vs. copepod, and is consistent among years (***Figure 1***). We estimated energy gain as ~1.2 million kJ/stomach fill. Forestomach evacuation rates for bowhead whales are unknown, but have been estimated in fin whales (*Balaenoptera physalus*) as 3-6 hours (Vikingsson 1997).

Stable isotope analysis is a common tool to estimate diets, construct food webs, and trace carbon sources. We applied bulk stable isotope analysis to bowhead whale gut contents to evaluate if ingested prey can shed light on feeding events and/or estimate stomach evacuation rates. This information is vital in assessing energy flow in the Arctic ecosystem and physiological response of important subsistence species, such as the bowhead whale, to prey abundance and prey quality changes.

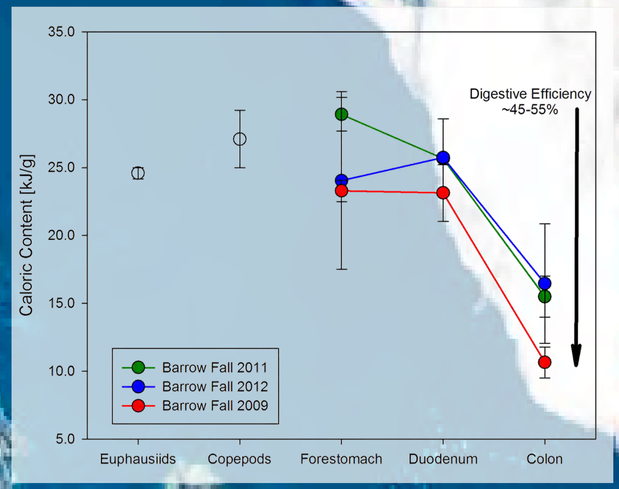
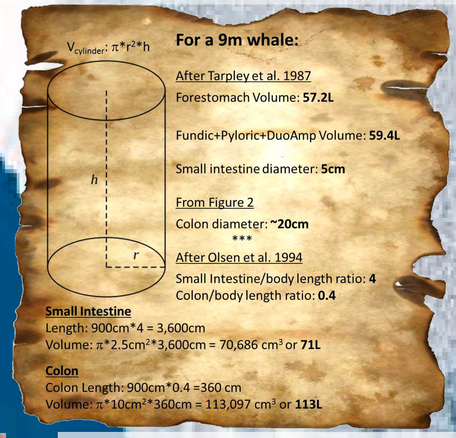


Figure 1: *Caloric content of prey (mean ± SD in kJ/g dry wt) and bowhead whale forestomach, duodenum, and colon. The drop in caloric density from duodenum to colon is consistent with lipid uptake in the small intestine. Efficiency of digestion ranged from ~45 to 55%.*

Results and Discussion

- Bowhead whales feed on a variety of prey, both pelagically and benthically
- Stable isotope ratios vary along the digestive tract within individual whales
  - ➢ $\delta^{15}N$ spans over 1 trophic level (e.g., 10.2-13.6‰ and 13.4-16.3 ‰)
  - ➢ $\delta^{13}C$ accompanies trophic level shifts, but is associated with changes in lipid content (↑lipid ↓$\delta^{13}C$ and vice versa)
- We identified 4-5 distinct stable isotope signature spikes (***Figures 3 and 4***)
- **Volume estimates of gut content indicate that isotope shifts reflect feeding events!**



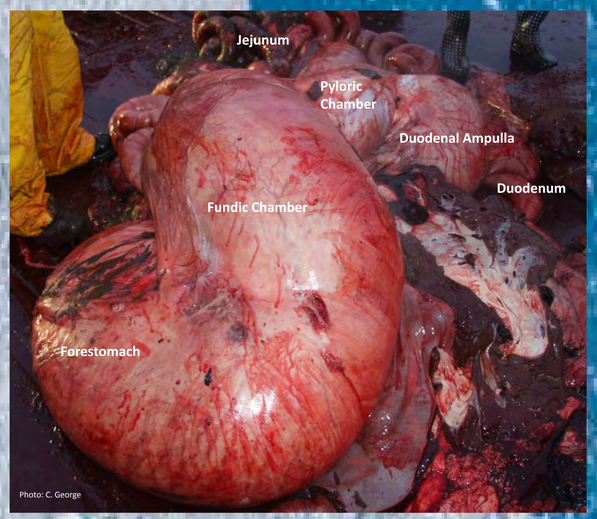
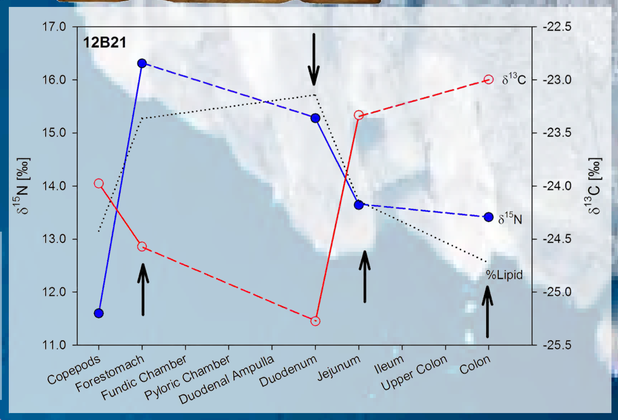
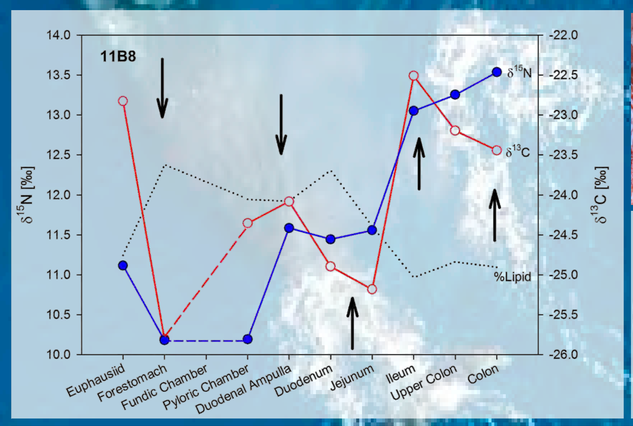
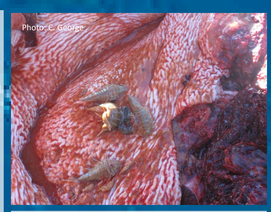


Figure 2: *Overview of bowhead whale stomach chambers and intestine.*

Figure 4: *Stomach of 12B21 (13.3m female) containing copepods. Black arrows in graph indicate changes in $\delta^{13}C$ and $\delta^{15}N$ in different gut compartments. Dotted line shows lipid content.*







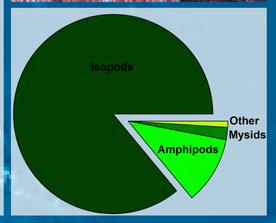


Figure 3: *Relatively unusual stomach of 11B8 (8.4m female) containing benthic prey. Black arrows in graph indicate changes in $\delta^{13}C$ and $\delta^{15}N$ in different gut compartments. Dotted line shows associated changes in lipid content.*

Methods

Samples of digestive contents were taken along the alimentary tract of bowhead whales and included (in order of food passage from oral opening) forestomach, fundic chamber, pyloric chamber, duodenum, duodenal ampulla, duodenum, jejunum, ileum, upper colon, and colon (***Figure 2***). Samples were collected from 7 whales harvested by Alaskan Natives for subsistence purposes in fall 2011 and 2012. Contents were frozen at -20°C until analysis at UAF. Fresh euphausiid and copepod prey were collected in the Beaufort Sea in 2012.

Samples were freeze-dried for a minimum of 48 hours and %water of prey and alimentary tract contents was determined as loss of mass during lyophilization. A sub-sample of contents of different compartments was lipid-extracted using chloroform:methanol in a Soxhlet solvent extraction procedure and %lipid (dry weight) calculated by loss of weight from removed fats.

Freeze-dried subsamples (not lipid-extracted) were analyzed for stable carbon and nitrogen isotope ratios at the UAF Alaska Stable Isotope Facility using a Costech Elemental Analyzer (ESC 4010) coupled to a Finnigan MAT DeltaPlusXL Isotope Ratio Mass Spectrometer. Instrument precision, expressed as one standard deviation from 12 analyses of a peptone working standard, was ±0.1‰ for both $\delta^{13}C$ and $\delta^{15}N$.

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