Spatial and Inter-Annual Variation of Bowhead Whale (*Balaena mysticetus*) Feeding Behaviour in the Eastern Canadian Arctic From Stable Isotopes of C, N and S

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ABSTRACT

This study investigates foraging ecology and habitat requirements of bowhead whales by using stable isotopes of carbon, nitrogen and sulfur. Skin biopsies from live and dead bowhead whales were collected at various locations in the Eastern Canadian High Arctic from 1987 to 2008. Our results indicate significant variations in stable isotopes of carbon and sulfur but not nitrogen among geographic locations. Gender, which was determined using genetic markers, had no significant effects on isotope ratios of carbon, nitrogen or sulfur. These patterns in a species with a narrow trophic niche, long-life expectancy and low fecundity, are discussed in the context of the changing climate, which may alter foraging success and predation risk relative to this long-lived species.

INTRODUCTION

The Arctic ecosystem is markedly unstable with profound seasonal variations in light intensity and duration, sea ice regime and primary productivity (Walsh 2008). Habitat suitability and prey availability for marine mammals in the Arctic and sub-Arctic areas are thus highly influenced by these variations. As a result, food supplies of pelagic species, such as bowhead whales (*Balaena mysticetus*), may vary widely within and between years and regions (Falk-Petersen *et al.* 2000).

Stable isotopes are useful to understand basic foraging ecology of animals as they provide information on carbon sources and trophic position. Geographical variations in naturally occurring stable isotopes might also be used as indicators for foraging reliance on different ecosystems.

OBJECTIVES

This study aims to determine bowhead whales probable feeding grounds and the comprehension of their habitat use in the context of their foraging ecology.

1) Identify the probable feeding grounds in the Eastern Arctic (for instance Baffin Bay versus Foxe Basin).

2) Determine regional and seasonal variations of feeding.

3) Identify the main bowhead prey (species/life stages preferences) and diet composition.

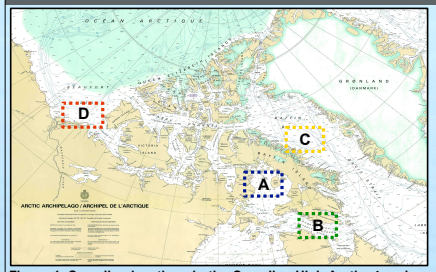
METHODOLOGY

Skin samples (n=107) were collected from bowhead whales in the Canadian Arctic through biopsy or sampling of the Inuit harvest.

Starting in 1987, bowhead samples were collected erratically among twelve locations: including Igloolik, Hall Beach, Repulse Bay, Pelly Bay, Coral Harbour, Pangnirtung, Admiralty Inlet, Wageham Bay, Sachs Harbour, Gjoa Haven, Cape Dorset, Mackenzie Delta.

Skin samples were freeze-dried to remove moisture and ground into a fine powder. Nitrogen isotope determination was performed on dried homogenized subsamples while lipids were removed prior to carbon isotope determination. Lipid extraction was performed following the Folch method (Folch *et al.* 1957) and a solvent consisting of 2:1 Chloroform:methanol (v/v). Skin samples were analyzed for stable isotope ratios of carbon, nitrogen and sulfur using a continuous flow ion ratio mass spectrometry (CF-IRMS) using a GV-Instruments IsoPrime coupled with a peripheral temperature controlled Euro Vector elemental analyser.

STUDY AREA



Crossbow for biopsie collection

Bowhead tagging

Traditional Inuit canoe

Figure 1. Sampling locations in the Canadian High Arctic. 4 regions; A) Foxe Basin, B) Hudson Strait, C) Baffin Bay and D) Western Arctic.

RESULTS

Table 1. Average $\delta^{13}C$, $\delta^{15}N$ and $\delta^{34}S$ values measured in bowhead whale skin samples per regions.

Regions	n	Latitude (dd)	Longitude (dd)	$\delta^{13}C/^{12}C$ (‰)	$\delta^{15}N/^{14}N$ (‰)	$\delta^{34}S/^{32}S$ (‰)
Foxe Basin	87					
Hall Beach		68.77	-81.24	-19.35	13.06	17.33
Igloolik		69.54	-81.32	-19.65	13.28	17.79
Repulse Bay		66.52	-86.22	-19.17	12.87	17.65
Hudson Strait	5					
Cape Dorset		64.25	-76.54	-19.76	12.78	18.68
Coral Harbour		64.15	-83.36	-19.19	12.77	15.97
Wageham Bay		61.35	61.58	-19.34	11.97	18.35
Baffin Bay	7					
Pangnirtung		66.13	-65.75	-19.99	13.27	16.85
Western Arctic	8					
Tuktoyaktuk		69.27	-133.44	-21.36	13.34	16.19
Sachs Harbour		72.00	-125.16	-20.26	14.66	16.90

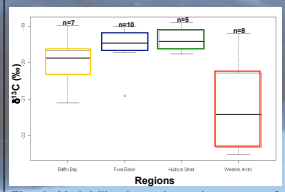


Fig. 2. Variability in carbon signatures of bowhead whale skin between four Arctic regions. Box plots show median, 25th and 75th percentiles and range.

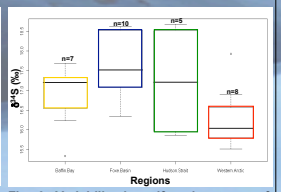


Fig. 3. Variability in sulfur signatures of bowhead whale skin between four Arctic regions. Box plots show median, 25th and 75th percentiles and range.

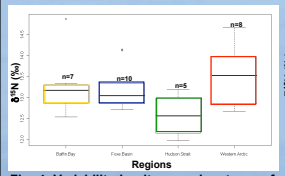


Fig. 4. Variability in nitrogen signatures of bowhead whale skin between four Arctic regions. Box plots show median, 25th and 75th percentiles and range.

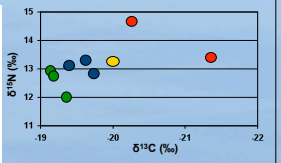


Fig. 5. Relationships between $\delta^{15}N$ and $\delta^{13}C$ per region. Green: Hudson Strait, Blue: Foxe Basin, Yellow: Baffin Bay, Red: Western Arctic.

Results: Spatial Differences

The factor region (n=4) had an effect on the spatial variation of carbon and sulfur but not on nitrogen.

Carbon values were significantly more depleted in the western Arctic than in the Eastern Arctic.

Table 2. ANOVA results examining the influence of region on the spatial variation of $\delta^{13}C$, $\delta^{15}N$ and $\delta^{34}S$.

Source	Df	SumSq	Mean Sq	F value	Pr(>F)
$\delta^{13}C$					
Region	3	15.34	5.11	7.79	<.0001
Residuals	25	16.42	0.66		
$\delta^{15}N$					
Region	3	2.35	0.78	1.89	0.1566
Residuals	25	10.34	0.41		
$\delta^{34}S$					
Region	3	8.23	2.74	3.43	0.0322
Residuals	25	19.97	0.80		

Results: Temporal Differences

Sample size (n=69) in Igloolik allowed to test for the effect of year (n=5) on the stable isotope ratios of C, N and S.

The year 1995 was significantly different from all the others for carbon while 2007 & 2008 were significantly different for sulfur (ANOVA with a posteriori Tukey-Kramer test).

Table 3. ANOVA results examining the influence of year on the variation of $\delta^{13}C$, $\delta^{15}N$ and $\delta^{34}S$ in Igloolik.

Source	Df	SumSq	Mean Sq	F value	Pr(>F)
$\delta^{13}C$					
Year	4	22.57	5.64	24.03	< .0001
Residuals	68	15.02	0.24		
$\delta^{15}N$					
Year	4	1.97	0.49	1.78	0.1429
Residuals	68	17.65	0.28		
$\delta^{34}S$					
Year	4	25.38	6.34	55.04	<.0001
Residuals	66	7.15	0.12		

Results: Gender differences

Differences in $\delta^{13}C$, $\delta^{15}N$ and $\delta^{34}S$ between males (n=25) and females (n=22) were assessed in all the bowhead whales sampled near Igloolik in 2007.

Results from a Welch Two Sample t-test indicated that there were no significant differences between gender in $\delta^{13}C$ (t=0.098, p=0.92), $\delta^{15}N$ (t=-0.724, p=0.47) and $\delta^{34}S$ (t=0.620, p=0.54).

No significant differences between males (n=27) and females (n=25) in $\delta^{13}C$ (F=0.04, p=0.85), $\delta^{15}N$ (F=0.23, p=0.64) and $\delta^{34}S$ (F=0.46, p=0.51) were found within the Foxe Basin region. Data for male and female were pooled together.

DISCUSSION

GENDER:
Since the stable isotope ratios of carbon, nitrogen and sulfur were not significantly different between male and female either at one site or between sampling areas, this suggest that male and female likely have similar foraging behavior.

TEMPORAL VARIATIONS:
Year had an effect on the stable isotope ratios of carbon and sulfur in Igloolik. Increase of freshwater inputs into the area in 1995 may have caused the depletion in the stable isotope ratio of carbon. According to the small sample size and the limited year data for some locations included in this study, temporal variation will be test in the other regions with newly collected samples in 2009 and 2010.

SPATIAL VARIATIONS:
Carbon and sulfur stable isotope ratios in bowhead from the three Eastern Arctic regions were less depleted and therefore more characteristic of a pelagic food web rather than a benthic one. The Mackenzie River exerts a strong freshwater influence on the Mackenzie shelf waters and is known to yield high terrigenous sources of carbon into the eastern Beaufort Sea - Amundsen Gulf area (Carmack *et al.* 2004). This is reflected in the $\delta^{13}C$ (more depleted) and the $\delta^{34}S$ (more depleted) of the bowhead sampled in this area.

FUTURE WORK

These results are preliminary and part of an ongoing study.

Next steps are:

- To compare microchemistry (stable isotopes and fatty acids) from bowhead skin and blubber samples with zooplankton samples.

- To define foraging habitat selection by looking at dive data and comparing satellite movement data with oceanographic features and sea ice data.

REFERENCES: Walsh, J.E. (2008) Ecological Application, 18:3-22, Falk-Petersen *et al.* (2000) Can. J. Fish. Aquat. Sci., 3:178-191, Carmack *et al.* (2004) Mar. Ecol. Prog. Ser. 277:37-50, Folch *et al.* (1957) J. Biol. Chem. 226, 497.