Deep-Sea Research I 69 (2012) 25–35

Contents lists available at SciVerse ScienceDirect

Deep-Sea Research I

journal homepage: www.elsevier.com/locate/dsri

# Composition, biomass and energetic content of biota in the vicinity of feeding bowhead whales (*Balaena mysticetus*) in the Cape Bathurst upwelling region (south eastern Beaufort Sea)

Wojciech Walkusz [a,b,*], William J. Williams [c], Lois A. Harwood [d], Sue E. Moore [e], Barbara E. Stewart [f], Slawomir Kwasniewski [b]

[a] Fisheries and Oceans Canada, Freshwater Institute, 501 University Crescent, Winnipeg, Man., Canada R3T 2N6
[b] Polish Academy of Sciences, Institute of Oceanology, 55 Powstancow Warszawy, Sopot, 81-712, Poland
[c] Fisheries and Oceans Canada, Institute of Ocean Sciences, 9860 West Saanich Road, Sidney, BC, Canada V8V 4L1
[d] Fisheries and Oceans Canada, 301-5204 50th Avenue, Yellowknife, NWT, Canada X1A 1E2
[e] NOAA Fisheries Science and Technology, 7600 Sand Point Way NE, Seattle, WA, 98115, USA
[f] Sila Consultants, 1218 Marchand Road, Howden, Man., Canada R5A 1J6

ARTICLE INFO

*Article history:*
Received 9 November 2011
Received in revised form
17 May 2012
Accepted 13 June 2012
Available online 21 June 2012

*Keywords:*
Bowhead whale
*Balaena mysticetus*
Feeding
Energetics
Zooplankton
Upwelling
Beaufort Sea

ABSTRACT

Bowhead whales (*Balaena mysticetus*) of the Bering-Chukchi-Beaufort population form annual late-summer feeding aggregations offshore of the eastern Tuktoyaktuk Peninsula and Cape Bathurst. This region is strongly influenced by episodic upwelling events. A systematic aerial survey (10% coverage) was flown over the eastern shelf on 2 August 2008, revealing large numbers of bowheads (est. 3500 individuals) in a clumped distribution over the continental shelf. Between 7 and 11 August 2008, zooplankton samples and hydrography were obtained from the vicinity of two bowhead feeding aggregations, one at the northeast edge of the continental shelf, and the second off the northeast shore of the Cape Bathurst. Dense aggregations of zooplankton were found in the lower part of the water column (below 40 m), on the shelf, in water with an upwelling signature. The zooplankton were largely resting phases of calanoid copepods (*Calanus hyperboreus* and *C. glacialis*) and collectively had twice the abundance, twice the biomass, three times the caloric density and thus six times the energy content of contemporaneous zooplankton samples from the western Canadian Beaufort Shelf. Although upwelling at Cape Bathurst is wind-driven and thus episodic in nature, its consistent delivery of zooplankton to the bowhead foraging area creates conditions attractive to bowhead whales, with an estimated 33% of the bowhead population present on the eastern portion of the shelf at the time of the August 2008 aerial survey.



## 1. Introduction

Bowhead whales (*Balaena mysticetus*), like other baleen whales, prey on dense aggregations of zooplankton, and require their prey to be sufficiently concentrated to meet their annual energy requirements (Laidre et al., 2007). In order to support this intensive predation by foraging whales, zooplankton communities must both be abundant and physical and biological processes must act to concentrate them (Thomson et al., 1986; LGL, 1988; Rogachev et al., 2008; Ashjian et al., 2010). Certain oceanographic features, including wind-driven upwelling, can lead to concentrations of zooplankton and thus these sites recurrently attract baleen whales. In particular, concentrations of primary-production grazers such as *Calanus* spp., play an important role in determining the distribution of right whales in the northwest Atlantic (Beardsley et al., 1996; Baumgartner and Mate, 2003; Baumgartner et al., 2011) and bowhead whales in the Arctic (e.g. Okkonen et al., 2001; Laidre et al., 2007; Rogachev et al., 2008; Pomerleau et al., 2011).

Bowhead whales of the Bering-Chukchi-Beaufort (B-C-B) population overwinter in the Bering Sea and spend the summer feeding in the Canadian Beaufort Sea and Amundsen Gulf (Burns et al., 1993). The main food of bowhead whales in the Canadian Beaufort Sea and offshore of nearby Kaktovik, Alaska is copepods, predominantly species *Calanus glacialis*, *C. hyperboreus* and *Limnocalanus macrurus* (LGL, 1988; Lowry, 1993; Krutzikowsky and Mate, 2000; Lowry et al., 2004; Pomerleau et al., 2011). The size of this bowhead population, based on the 2001 census at Point Barrow, is 10,470 with a 95% confidence interval of 8100–13,500 whales (George et al., 2004).

* Corresponding author at: Fisheries and Oceans Canada, Freshwater Institute, 501 University Crescent, Winnipeg, Canada, MB R3T 1R2. Tel.: +1 20 4984 5541.
*E-mail address:* walwo@iopan.gda.pl (W. Walkusz).

0967-0637/$ - see front matter Crown Copyright © 2012 Published by Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.dsr.2012.05.016

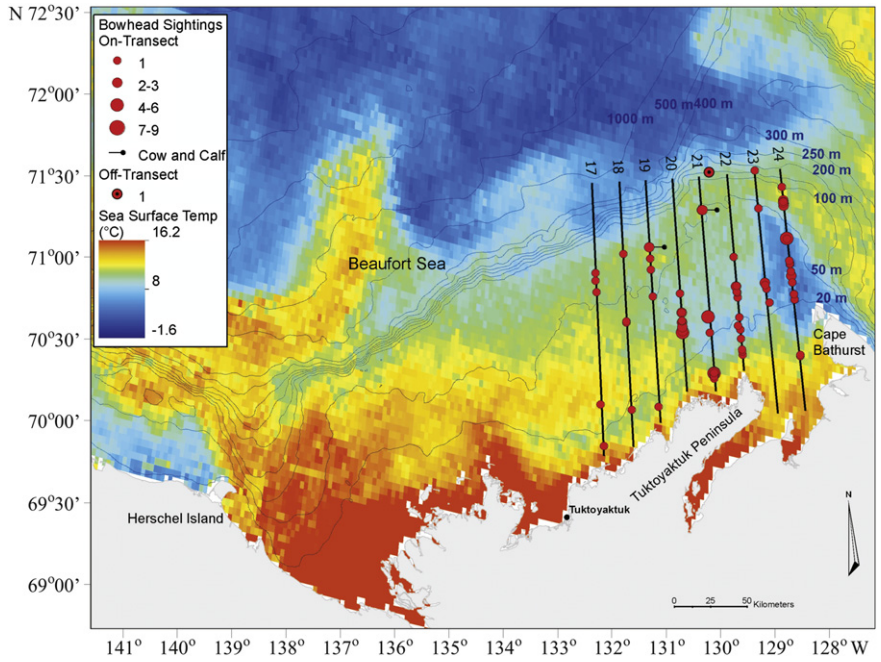


**Fig. 1.** Location of study area, aerial survey transect lines, bowhead whales sighted and sea surface temperature, 2 August 2008.

By early to mid August, oceanographic conditions develop that favour the concentration of the bowhead's planktonic prey in certain areas of their summer range in the Beaufort Sea (Thomson et al., 1986). At this time, the whales recurrently aggregate to feed in four or five specific areas, some staying in the Canadian Beaufort Sea and Amundsen Gulf for 3 months or longer, until their return fall migration (Richardson et al., 1987; Harwood and Smith, 2002; Ashjian et al., 2010; Moore et al., 2010; Quakenbush et al., 2010). The most important and regularly used of these recurrent feeding areas develops during late summer of most years over the continental shelf offshore of the Tuktoyaktuk Peninsula, extending eastward to include waters offshore of Cape Bathurst (Fraker and Bockstoce, 1980; Harwood and Borstad, 1985; Richardson et al., 1987; McGhee, 1988; Harwood and Smith, 2002; Fig. 1). This suggests particularly bountiful and persistent pelagic communities of zooplankton are available to foraging bowhead whales in the area.

Zooplankton have uneven and patchy distribution in the ocean (Folt and Burns, 1999). Such irregular zooplankton occurrence has been documented for the Beaufort Sea (Walkusz et al., 2010) and was found to have a strong influence on bowhead whale foraging behaviour and distribution (LGL, 1988). Oceanographic features that lead to upwelling of deep waters are particularly important in determining distribution of, first of all, zooplankton (Harwood and Borstad, 1985; Thomson et al., 1986; LGL, 1988). Cape Bathurst is known for its strong upwelling events which bring cold, Pacific-derived water to the surface (Williams and Carmack, 2008). This phenomenon and its consequences are well reflected in extremely abundant benthic communities (Conlan et al., 2008).

The objective of this study is to describe bowhead distribution in the context of late-summer oceanographic features, which may lead to the concentration of whales' prey in the shelf area offshore of the eastern Tuktoyaktuk Peninsula and Cape Bathurst. In addition, we examine the quality and quantity of prey available to feeding bowhead whales in these areas. Because there is no regular subsistence harvest of bowhead whales in the Canadian Beaufort Sea, no opportunities exist to examine their stomach contents, so the only direct method to study their diet is to collect net samples as close to foraging whales as possible.

**Table 1**
List of sampling stations at Cape Bathurst (SWB), on the shelf N of Cape Bathurst (WFA) and in Franklin Bay (FB) in summer 2008.

| Date | Station name | Station depth [m] |
|---|---|---|
| 7 August | SWB 1 | 39 |
| 8 August | SWB 0 | 130 |
| 8 August | SWB 0_75 | 75 |
| 8 August | SWB 0N | 130 |
| 10 August | WFA 1 | 60 |
| 10 August | WFA 2 | 54 |
| 10 August | WFA 3 | 60 |
| 10 August | WFA 4 | 60 |
| 11 August | SWB 02 | 130 |
| 11 August | SWB 0_60 | 60 |
| 11 August | SWB 0N2 | 130 |
| 14 August | FB | 50 |

## 2. Material and methods

### 2.1. Hydrography, plankton and ship-board whale sightings

Data for these components of the study were collected between 7–11 August, 2008 during a CCGS *Nahidik* cruise in the Beaufort Sea. In total, we took measurements and samples at 11 stations (Table 1; Fig. 2) where bowhead whales were observed from the ship and confirmed to be actively feeding. These stations were in two general areas, one located off the east shore of the Cape Bathurst, over the steep depth gradient into Amundsen Gulf (SWB stations), and the second, approximately 50 km north of Cape Bathurst at the eastern edge of the Canadian Beaufort Shelf (CBS) in approximately 60 m of water (WFA stations). The ship-board bowhead spotting protocol involved continuous 24-h watches from the bridge by the navigating officer and/or seaman, with coverage extending from the bow to 90° off either side of the ship, and out to distances up to 5 km, depending on sea states and weather conditions. When bowhead whales were spotted, approach was made to verify their behaviour and sample for zooplankton in their vicinity.