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Heavy metal and mineral concentrations and their relationship to histopathological findings in the bowhead whale (*Balaena mysticetus*)

Cheryl Rosa[a,d,*], *John E. Blake*[a], *Gerald R. Bratton*[b], *Larissa-A. Dehn*[a,e], *Matthew J. Gray*[c], *Todd M. O'Hara*[a]

[a]*Institute of Arctic Biology, University of Alaska Fairbanks, 311 Irving I Building, Fairbanks, Alaska 99775, USA*
[b]*Department of Veterinary Integrated Biosciences, Texas A&M University, College Station Texas 77843, USA*
[c]*Department of Forestry, Wildlife and Fisheries, University of Tennessee, Knoxville, Tennessee 37996, USA*
[d]*Department of Wildlife Management, North Slope Borough, P.O. Box 69, Barrow, Alaska 99723, USA*
[e]*Alaska Department of Fish and Game, Division of Commercial Fisheries, 1300 College Road, Fairbanks, Alaska 99712, USA*

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ABSTRACT

The bowhead whale (*Balaena mysticetus*) is a species endangered over much of its range that is of great cultural significance and subsistence value to the Inuit of Northern Alaska. This species occupies subarctic and arctic regions presently undergoing significant ecological change and hydrocarbon development. Thus, understanding the health status of the Bering–Chukchi–Beaufort Sea (BCBS) stock of bowhead whales is of importance. In this study, we evaluated the concentrations of six essential and non-essential elements (Zn, tHg, Ag, Se, Cu and Cd) in liver and kidney of bowhead whales ($n=64$). These tissues were collected from the Inuit subsistence hunt in Barrow, Wainwright and Kaktovik, Alaska between 1983 and 2001. Reference ranges of these elements (including previously reported data from 1983–1997) were developed for this species as part of a health assessment effort, and interpreted using improved aging techniques (aspartic acid racemization and baleen isotopic ^{13}C methods) to evaluate trends over time with increased statistical power. Interactions between element concentrations and age, sex and harvest season were assessed. Age was found to be of highest significance. Sex and harvest season did not effect the concentrations of these elements, with the exception of renal Se levels, which were significantly higher in fall seasons. In addition, histological evaluation of tissues from whales collected between 1998–2001 was performed. Associations between concentrations of Cd in kidney and liver and scored histopathological changes were evaluated. Liver Cd concentration was strongly associated with the degree of lung fibromuscular hyperplasia ($P=0.001$) and moderately associated with the degree of renal fibrosis ($P=0.03$). Renal Cd concentration influenced the degree of lung fibromuscular hyperplasia and renal fibrosis ($P=0.01$). A significant age effect was found for both pulmonary fibromuscular hyperplasia and renal fibrosis, indicating age may be a causative factor. Improvements in aging techniques and the addition of histological indices help clarify the relationships between elements and the influence of life history parameters on concentrations of these elements and potential impacts on health. These data provide essential baseline input useful for

* *Corresponding author.* North Slope Borough, Department of Wildlife Management, P.O. Box 69, Barrow, AK 99723, USA. Tel.: +1 907 852 0350; fax: +1 907 852 0351.
E-mail address: Cheryl.Rosa@north-slope.org (C. Rosa).

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monitoring the effects of arctic ecosystem change as it relates to global climate change and industrial development, as well as help inform epidemiological studies examining the public health implications of heavy metals in subsistence foods.

1. Introduction

The toxic effects of metals and their transport through the arctic environment and food chain have been the subjects of recent studies (Mackey et al., 1996; Wagemannn et al., 1998; Skaare, 1996; Woshner et al., 2001; Dehn et al., 2005, 2006a, b). Anthropogenic contamination of air, water, soil and food impact the fauna of the Arctic and consumers of these animals (Muir et al., 1992; Stirling et al., 1999; Bard, 1999; Dehn et al., 2006b). Heavy metals and minerals, including toxic metals, occur naturally in the environment and many are essential for life (Goyer, 1996). However, certain toxic metals appear to be increasing in the environment (Bard, 1999) and elements that are critical for life at a given concentration may lead to loss of organ function or death when they occur at certain levels (Goyer, 1996). The toxic effect of heavy metals manifested in an organ is mainly a function of concentration and exposure time, because many toxicants bioaccumulate. Thus, age can be an important factor in wildlife toxicology. Recent advances in aspartic acid racemization and ^{13}C isotope technology allowed the development and optimization of aging protocol in large cetaceans (George et al., 1999; Lubetkin et al., 2004; Rosa et al., 2004). These methods help minimize the variability associated with using body length as a proxy for age in long-lived cetacean species.

Bowhead whales (*Balaena mysticetus*) are mysticetes that feed on a low trophic level (i.e. zooplankton), which is reflected in the concentration of heavy metals and minerals in their organs (Bratton et al., 1993; Woshner et al., 2001; Krone et al., 1999). For example, studies have reported bowhead whale tissues to have higher cadmium (Cd) concentrations than would be expected, especially compared to other marine species and terrestrial animals from higher trophic levels (Bratton et al., 1993; Woshner et al., 2001; Dehn et al., 2005, 2006a). Most other elements have been found in low concentrations; however, elements may have antagonistic and synergistic effects on their accumulation (Ikemoto et al., 2004; Goyer, 1996). Many metals and minerals are known to interact with other elements and proteins, including selenium (Se) and mercury (Hg), and copper (Cu), Cd and metallothionein (MTH; Wagemannn et al., 1984; Woshner et al., 2001; Ikemoto et al., 2004). These interactions are important to explore, as they may determine the bioavailability of the toxicant or the effect that is seen in a particular species. Marine mammals produce MTH as a physiologic adaptation as a defense against toxicants. Metallothioneins are proteins that serve metal binding and transport functions and are induced in response to a variety

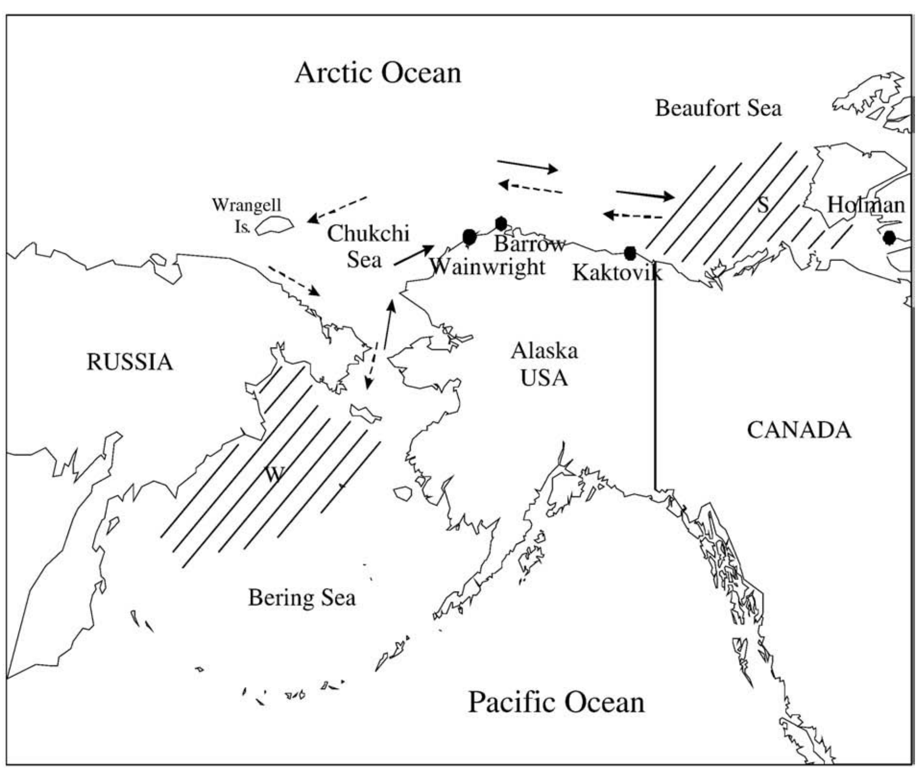

Fig. 1 – Bowhead whale sample collection occurred in Wainwright, Barrow and Kaktovik, Alaska between 1983 and 2001. (Modified from Hoekstra et al., 2003). S = summer habitat, W = winter habitat.