A preliminary assessment of the nutritive value of select tissues from the bowhead whale based on suggested nutrient daily intakes

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ABSTRACT

Worldwide the consumption of marine mammals by humans occurred for many centuries. Many island and coastal Alaskan communities still depend on marine mammals for nutritional, cultural, health, medicinal, economic, and spiritual well being. These communities know these benefits exist but in most cases a well designed quantitative assessment of nutrient values has been lacking. This study focuses on bowhead whales (*Balaena mysticetus*) landed during subsistence hunts. We assess tissues that are consumed to quantify the nutritional composition and relate this to well documented nutritional "daily requirements." We evaluate the uncooked or unprocessed nutritional value of many bowhead whale-based foods. Based on a person eating 100 grams (3 ounces) of food we determined what percent of the daily requirement is met (e.g., 50%, means that this 100 g portion of food provides half of the specific nutrient required for a day for an adult male). As for most tissues studied epidermis ("skin") is a poor source of carbohydrates (<5%) and sugars, vitamin C, and beta carotene but represents a good source for protein (42%), dietary fiber (21%), vitamin E (12%), and many elements. Blubber, a component of *maktak* (a food comprised of the epidermis and underlying blubber), is rarely eaten alone and offers 8% of needed vitamin A, 10% protein and little carbohydrate (<4%), but is a very good source of polyunsaturated fatty acids (PUFAs) (189%) and many elements. Skeletal muscle (meat) is a poor (<5%) source of fat, PUFAs, dietary fiber, and carbohydrate. However, it provides approximately 45% of needed protein and $\geq$ 10% for some of the Vitamin B compounds and many elements. Kidney is a good source of fat (11%) and protein (28%) but not carbohydrate (2%). Kidney provides nearly 16% of the needed PUFAs and is an excellent source of many elements. Heart is a good source of protein (40%) and many elements. Tongue is a good source of fat (82%), PUFAs (161%), protein (27%), calories (30%), vitamin A (16%), and some elements. Intestinal tissue is a good source of protein (37%) and many elements. Many important essential fatty acids (omega-3 class) are present in these tissues and are known to be important in prevention of heart disease and diabetes; and are essential for neonatal development (i.e., neural tube). These data clearly indicate that important nutrients are provided by bowhead whale tissues (uncooked) to human consumers.

INTRODUCTION

Bowhead whales (*Balaena mysticetus*) inhabit many regions of the Arctic year-round. The consumption of marine mammals, such as the bowhead whale, by humans has occurred for many centuries and has provided many basic nutrients to support healthy island and coastal communities (e.g. Egeland et al., 1998). Typically this dependence has been expressed as "need" in some reports (Braund and Moorehead, 1995; Braund, 2002). However, these assessments do not directly address the nutrients provided to the people.

Many coastal Alaskan communities depend on marine mammals for nutritional, cultural, health, medicinal, economic, and spiritual well being (Egeland et al., 1998). These subsistence activities are important for cultural identity, physical activity, self reliance, meaningful productive work and are commonly the center of social activity (Egeland et al., 1998). These communities know these benefits but in most cases a well designed quantitative assessment of these critical sources and the actual nutrient content has not been made.

Daily requirements criteria come in many forms including Recommended Daily Allowances (RDA), Adequate Intakes (AI), Dietary Reference Intakes (DRI), and for upper limits of consumption as Tolerable Upper Intake Levels (UL) as described by the National Academy of Science (1998). For nutritional needs these reference values are intended to provide what amount of a particular nutrient or class of nutrients is required each day. Using these values one can select a meal mass or portion weight (i.e., 100g or 3 ounces of meat) of a food item and determine what percentage of the "daily requirement" is met by this amount of tissue for the consumer. The nutritional needs of the consumer can vary based on age, reproductive status, body weight, gender, specific physiological or disease conditions, and other factors. It is not the intent of this paper to cover this wide range of human conditions or life stages (i.e., fetal to geriatric). Some studies have described subsistence diets in Alaska (e.g., Jensen and Nobmann, 1994; Nobman, 1993) but not in detail for the bowhead whale and the numerous types of tissues consumed.

This study provides nutrient information on a variety of tissue types from the bowhead whale to develop a quantitative measure of the nutritive value for humans. These data are expressed in terms of the consumer in the form of the proportion of the daily requirement met by a 100 g or 3 ounce portion of the tissue. This type of data adds to the traditional assessment of "need" (Braund and Moorehead, 1995; Braund, 2002), and provides direct evidence of the importance of these food items and the specific nutrients within these foods for maintaining health and preventing disease in humans. These nutrient data should also be used when giving balanced advice related to the presence of contaminants and the associated risks to human health (Hansen, 2000). Assessing nutrient levels in these tissues is also important for monitoring the health status of the bowhead whale population. However, to date sources of funds have not been readily available to address nutrients to the same degree as for contaminants. This apparent funding and scientific imbalance should be addressed. With this manuscript we start to alleviate this apparent imbalance by presenting nutrient concentrations in various tissues of the bowhead whale in the context of the human consumer.

MATERIALS AND METHOD

Field sampling of bowhead whales

Field sampling of the bowhead whale has been previously described (O'Hara et al. 1999). Full thickness blubber cores and various tissues (epidermis, liver, kidney, muscle) from twelve (n=12) subadult, female bowhead whales were provided by Native subsistence hunters in Barrow, Alaska USA (Figure 1) from 1997 – 1998. Additional samples of heart, tongue and intestine were collected from seven male and female bowhead whales in April-May, 2003 (whale identifications: 03B1 – 03B7). Samples were collected by staff at the Department of Wildlife Management with the endorsement of the Alaskan Eskimo Whaling Commission (Barrow, Alaska, USA). Blubber cores from approximately the same location on each whale (dorsal midline, 1 meter caudal to the blowhole) were collected. Life history information was recorded from each whale harvested (body length, baleen length, sex, etc.). Body length classification (length cohort) was based on lengths at sexual maturation and known age characteristics (juveniles: 6m – 8.9m; subadults: 9m – 12.9m; adults: >13m) (George et al. 1999).

Samples were temporarily stored at -20˚C at the Arctic Research Facility (Barrow, Alaska, USA) and temperature was maintained during transport to the National Water Research Institute (Environment Canada, Burlington, Ontario, Canada) under U.S. Export and Canadian Import permits in accordance with the Convention on International Trade in Endangered Species (US694250 and CA-CW-IM-0053-00, respectively) and via prevision of the U.S. Marine Mammal Protection Act (Permit No. 782-1399).

All samples were homogenized and stored at -20˚C in pre-cleaned glass containers. Based on previous work *maktak* composition was estimated based on proportions of epidermis and blubber typically consumed (Hoekstra et al., 2004; SC/56/E3). Representative samples of uncooked bowhead whale *maktak* were prepared using an epidermis-to-blubber size ratio of 1:2 (i.e. typically consumed dimension). Due to

the amount of tissue required for the analysis of multiple nutrient parameters, bowhead whale blubber, *maktak*, epidermis, muscle and liver tissues were pooled by tissue type into 3-4 composites, and each pool consisted of subsampled tissues from the same 4 subadult (body length: < 12 m) female whales. Tongue, heart, and intestine were each combined by tissue type into a single composite by combined equal amounts of tissue from each of the seven whales sampled (03B1-7). Overall, Pool 1 comprised four bowhead whales (97B31, 97B30, 98B24, 97B25), and Pool 2 consisted of 4 bowhead whales (97B19, 97B14, 97B24, 98B11) for each of the following tissue types: liver, blubber, epidermis, kidney, and muscle. A third pool, Pool 3, included whales 97B22, 98B12, 97B21, and 98B10 for each of the following tissue types: liver, blubber, and epidermis. Thus 3 pools (representing 12 animals) were prepared for liver, blubber and epidermis, and 2 pools (representing 8 animals) for kidney and muscle. Pooling for heart, tongue and intestine consisted of a single pool (Pool 4) and included 8 bowhead whales.

Analytic methods

Tissues were analyzed by Maxxam Analytics for various nutrients (Mississauga, Ontario, Canada). The endpoints include (g/100g) moisture, fat, protein, ash, carbohydrates, cis-polyunsaturated fatty acids (PUFAs), cis-monounsaturated fatty acids (MUFAs), saturated fatty acids, trans-fatty acids, total sugars, glucose, sucrose, maltose, lactose, and total dietary fiber. Components measured at mg/ 100g are cholesterol, vitamin C, Ca, Cr, Cu, Fe, Mg, Mn, Mo, P, K, Se, Na, and Zn; and at ug/100g are beta carotene, and retinol (Vitamin A as RE or retinol equivalents). Calories and kilojoules were determined as well. Protocol was based on established methodology by the *Association of Official Analytical Chemist's (AOAC) Official Methods of Analysis* (AOAC, 2000) and is briefly described herein. Laboratory standards and blanks were used in each method and in accordance with AOAC protocol.

Lipids and cholesterol (Maxxam Analytics Laboratory)

Fat and fatty acids in all tissues were extracted with boron trifluoride in methanol (125 g BF_3 in 1 L methyl alcohol). Samples were partitioned with *n*-heptane and saturated sodium chloride, homogenized, and diluted prior to analysis (as required). Total fat (sum of fatty acids expressed as triglycerides) and classes of fatty acids were quantified using a flame ionization detector after compound separation by gas chromatography using a SP2560 column (Supelco Canada, Oakville, Ontario; 100 m length × 0.25 mm internal diameter (i.d.) × 0.2 μm film thickness) (AOAC Methods 969.33 and 996.06).

Cholesterol content of each tissue was determined by drying approximately 5.0 g each sample in an oven at 100 ºC to a constant weight. Each sample was homogenized with 100 mL of anhydrous methanol. The homogenate was filtered under vacuum using Whatman No. 1 paper and 2 g of diatomaceous earth. A 100 mL aliquot of the methanol-lipid extract was subsequently filtered through sodium sulfate (Na_2SO_4) and evaporated to dryness under a gentle stream of N_2 in a 90 ºC H_2O bath. The residue was dissolved in 70 mL of petroleum ether, filtered with Na_2SO_4, dried under N_2 and re-dissolved with 8 mL of concentrated KOH (60 g KOH in 40 mL H_2O), transferred to a condenser with 100 mL of reagent alcohol (ethyl alcohol-methanol-isopropanol at a volume ratio of 90: 5: 5). Approximately 100 mL of benzene was added to the sample, which separated the sample into two distinct layers. The aqueous (i.e. lower) layer was discarded and the top layer was rinsed with benzene, filtered with Na_2SO_4, and evaporated to dryness, and re-suspended with 3 mL of *N*,*N*-dimethylforamide.

Samples were derivatized with 0.2 mL hexamethyldisilazane and 0.1 mL trimethylchlorosilane and a 5α-cholestane was added as an internal standard. Compound separation was completed using 2.4 m × 3 mm (internal diameter, i.d.) U-shaped glass column packed with 0.5% Apiezon L on 80-100 mesh Gas-Chrom Q (Alltech-Applied Science, Mississauga, Ontario). Quantification of the derivatized cholesterol was carried out using a H_2 flame ionization detector (AOAC Method 976.26).

Other nutrient content (Maxxam Analytics Laboratory)

To determine total protein content, each sample was dried (AOAC Method 931.04) and combusted at 950 ºC in pure (99.9%) O_2. The nitrogen content (N_2) of the sample, as measured by thermal conductivity detection, and converted to equivalent protein (wet weight basis) using a multiplier of 6.25 (AOAC Method 990.03).

The ash content of each tissue sample was determined by combining 3-5 g of tissue with a magnesium acetate solution (4.054 g in 50 mL water and 950 mL ethanol). Samples were dried in a furnace at 700 ˚C and re-weighed. Ash content was inferred from the differences between pre- and post-treated sample weights (AOAC Method 936.07).

Total dietary fiber content of each tissue was determined by subjecting duplicate portions of each tissue to sequential enzymatic digestion by heat stable α-amylase, protease, and amyloglycosidase to remove starch and protein. The digestate was treated with 225 mL 95% ethanol at 60 ˚C. The alcohol-treat enzyme digestate was eluted through a pre-weighted filtering crucible (45-60 μm pore size) containing 1 g of Celite with a 78% ethanol solution under a gentle vacuum. The digestate was rinsed three times each with 15 mL portion of 78% ethanol, 98% ethanol, and acetone. The crucible containing the residue was dried and weighted. Total dietary fiber was calculated by subtracting the weight of the dry crucible (plus Celite) from the residue weight (AOAC Method 991.43).

The sugar profile (fructose, glucose, lactose, maltose, and sucrose) of each tissue was determined by centrifuging 10 g of homogenized tissue with 50 mL of petroleum ether. The sample was centrifuged and the supernate was discarded. The residue was pulverized, combined with 100 mL of H_20 and placed in an 85 – 90 ˚C water-bath. The sample was subsequently re-centrifuged, supernate removed and filtered via 0.45-μm syringe filter. Fifty (50) μL of filtered supernate was injected into a 300 × 4 mm (i.d.) μ-Bondapak carbohydrate column (Waters Associates, Mississauga, Ontario). Sugars were separated using liquid chromatograph, with $CH_3CN•H_2O$ as the mobile phase, and quantified by a refractive index detector (AOAC Method 980.13).

Total carbohydrate levels were determined from the analytical results of total fat, moisture, ash, and protein; and inferred from the sum difference of these parameters from 100. Total calories (and kJ) were determined for each sample using the Atwater Method; the sum of the application of appropriate factors to total fat (9), carbohydrate (4) and protein (4) content (AOAC, 2000).

Vitamin A, C (Maxxam Analytics Laboratory)

Approximately 10 g of tissue was homogenized with ethanolic pyrogallol and ethanolic KOH solutions for 18 h. A 3 mL portion of the digestate was combined with 2 mL H_20 and 7 mL hexane-diethyl ether (85:15 by volume), vortexed for 30 s, and subsequently centrifuged to facilitate separation. The organic phase (top aqueous layer) was transferred and combined with 1 mL hexadecane (1 mL hexadecane in 100 mL hexane) solution to prevent the destruction of the vitamin. Samples were evaporated to dryness under a gentle stream of N_2 and re-dissolved in *n*-heptane. A 100 μL of test solution was injected into a high-performance liquid chromatograph (HPLC) equipped with a UV detector (AOAC Methods 992.04 and 992.06).

Levels of vitamin C (ascorbic acid) in each tissue was determined by pulverizing each dried sample with methaphosphoric acid. Samples were filtered and mixed with 2 g acid-washed Norit (1 L HCl with 200 g Norit Neutral; Fisher Scientific, Mississauga, Ontario). Samples were shaken vigorously and filtered through Whatman No. 12 paper. 5 mL of the filtrate was mixed with dilute boric acid and *o*-phenylenediamine and vitamin C concentrations determined using HPLC with electrochemical detection (AOAC Methods 967.22 and 984.26).

Element analysis (Maxxam Analytics Laboratory)

Bowhead whale tissues were analyzed for essential elements (Ca, Cr, Cu, Fe, Mg, Mn, Mo, P, K, Se, Na, and Zn) by inductively coupled plasma – atomic emission spectrometry (ICP-AEC). Samples were homogenized, digested in mineral acids and analyzed according to USEPA Method 6010 (U.S. EPA, 1996).

Dietary reference intake calculations

Dietary Reference Intakes or DRIs (Food and Nutrition Board - National Academy of Sciences, 1998) as Recommended Daily Allowance (RDA) or Adequate Intake (AI) were used to calculate the proportional (%) amount a 100 g (0.22 lb or 3 ounce) meal would provide to a consumer for a specific nutrient. For example: the average concentration of a nutrient in a tissue = X mg of a nutrient /100g and the RDA or AI is Y mg/day. The ratio of these values gives Z % which equals the proportion of the daily requirement satisfied by consuming 100 g of a tissue for a specific nutrient for that day.

Therefore,
(X mg of a nutrient/ 100g of tissue)/ (Y mg/day as RDA or AI) * 100 = Z% of daily requirement provided by 100g of the tissue for a nutrient.

RDAs and AIs may both be used as goals for individual intake. RDAs are set to meet the needs of almost all (97% to 98%) individuals in a group. Since daily intake needs vary by gender, reproductive status and age for some nutrients we selected the daily intake levels for men ages 31-50. Different cohorts may have increased or decreased nutritional needs. Saturated fatty acids, mostly used for energy, and cholesterol are adequately synthesized by the body and thus no suggested intake is available. It is suggested for most humans that these nutrients be limited in a balanced diet. Sodium (Na), chloride (Cl), and potassium (K) minimum requirements of healthy persons (> 18 years, 70 kg) are 500, 750 and 2000 mg per day (USDA, 2000; The National Academy of Sciences, 1998) and are very rarely limited in the diet.

RESULTS AND DISCUSSION

Overall

Many nutrients are present in numerous tissues of the bowhead whale at adequate (>10% of the RDA or AI met by 100 g or 3 ounces of that specific tissue) to excellent (meets or exceeds the RDA or AI for 100 g or 3 ounces of that specific tissue) levels. These abundant nutrients will be outlined below by tissue type, classes of nutrients, and in Tables 1-7. As expected, raw bowhead whale tissues are a poor source of some nutrients including carbohydrates (<5%) and sugars, vitamin C, and beta carotene. In some cases these nutrients were below the level of detection of the assays employed. Numbers presented as % in parentheses with a specific nutrient indicate what proportion (%) of the daily requirement for that nutrient is met by consuming 100 g or 3 ounces of that tissue for a male adult 31-50 years of age. It does not represent the concentration of the nutrient in the tissue; the nutrient concentration values are presented in the Tables and in some cases in the text (e.g., g/100g).

Tissue type specific results

Epidermis (Table 1)

As for most tissues studied epidermis is a poor source of carbohydrates (<5%), sugars, vitamin C, and beta carotene. Epidermis represents a good source for protein (42%), dietary fiber (21%), vitamin E (12%, Rosa and Mazzaro, pers comm), and for Cr, Mo, P, K, Na, and Zn (>10%). Retinol (vitamin A) concentration was significantly higher in the epidermis (1.65 ug/g) than in the deeper blubber layers (Rosa and Mazzaro, pers comm) but is not a good source of vitamin A as compared to other bowhead whale tissues. Tocopherol (vitamin E) was significantly higher in epidermis (17.2 ug/g) and the intermediate layer (middle 40-60%) of blubber than in the innermost and outermost blubber layers (i.e., stratified) (Rosa and Mazzaro, pers comm).

Muscle (Table 2)

Skeletal muscle is a poor (<5%) source of fat, dietary fiber, and carbohydrate. However, it provides approximately 45% of needed protein and $\geq$ 10% for the following elements Cu, Mo, Fe, P, K and Zn. Nobmann (1993) provided data that indicated muscle provided 61%, 16%, and 46% of riboflavin, thiamine, and niacin, and 11% for PUFAs. Muscles of many types are consumed and these analyses are for only lumbar area (vertebrae in the abdominal area) skeletal muscle. Variations of nutrient content likely occur among the muscle groups and types and could be considered for further investigation.

Liver (Table 3)

Liver represents a good source of protein (36%), but is a poor source of carbohydrates (2%). Liver is a very rich source of retinol or vitamin A (2153%), vitamin E (515%), and a good source (>10%) for Cr, Cu, Fe, Mo, K, Na, P, and Zn. In another study, liver contained the highest concentrations of vitamin A (4599 ug/g) followed by epidermis, blubber and serum, and liver contained the highest concentration of vitamin E (772.6 ug/g) followed by serum, epidermis and blubber (Rosa and Mazzaro pers comm). Liver is not commonly eaten but no intensive dietary surveys have been conducted to better quantify this observation that is based mostly on the authors' experiences in Barrow, Alaska. The maximal intake, or UL (3000 ug vitamin A per day), of liver for vitamin A based on a mean of 21533.3 RE/100g and 10766.7 RAE/100g

(215.3 and 107.7 ug retinol/g of liver) equals consumption ranges from 14 to 28 g of liver per day. The amount of retinol estimated to be in the liver depends on the amount of provitamin A verses preformed vitamin A present (not measured in this study). Assuming a range of retinol measured that is preformed vitamin A one can only consume 13.9 to 27.9 grams of liver per day to remain at or below the suggested UL. This limits dietary intake more than contaminants studied in blubber and liver of the bowhead whale (SC/56/E3).

107.7 or 215.3 ug retinol/g of liver * X g of liver per day = 3,000 ug per day,
X =27.9g or 13.9g of liver per day

Kidney, heart, tongue, intestine (Tables 4 and 5)
Kidney is a good source of fat (11%) and protein (28%) but not carbohydrate (2%) nor total fiber (3%). Kidney provides 16% PUFAs, and is an excellent source of Cr, Cu, Fe, Na, Mo, P, and Zn. Heart is a good source of protein (40%), and the elements of Cu, Fe, Na, K, Zn, and P. Tongue is a good source of fat (82%), cis-PUFAs (161%), protein (27%), calories (30%), vitamin A (16%), and Cr, Cu, Na, and Fe. This nutrient rich status of tongue results from the very integrated blubber, fat, and muscle of the tongue (highly "marbled"). Intestinal tissue is a good source of protein (37%), and for the elements of Cu, Na, K, Fe, P and Zn.

Blubber and maktak (Tables 6 and 7)
Blubber, a component of *maktak*, is rarely eaten alone and offers 8% of needed vitamin A, 10% protein and little carbohydrate (4%), but is a very good source of PUFAs in general (189%), and Cr, Cu, and Mo. It is important to recall blubber composition is stratified for many components. Retinol and ∝-tocopherol were the major forms of vitamin A and E detected, respectively (Rosa and Mazzaro, pers comm). Preliminary data indicates that vitamin E is highest in the intermediate layers of the blubber (middle 40-60%, Rosa and Mazzaro, pers comm). The most commonly consumed blubber is that underlying the epidermis (eaten as *maktak*) and this value is reported in Table 5. Retinol and tocopherol (vitamin E) concentrations varied from outer to inner layers of blubber, and this stratification of nutrients was previously described by Tornero et al. (2002) for retinoids in blubber of common dolphins *(Delphinus delphis* and *Delphinus capensis)*.

Fatty acids are quite numerous and Wetzel and Reynolds (2003) identified 45 (Table 7) using nitrogen (picolinyl) ester derivatization. Table 7 lists the fatty acids according to abundance as "major" (> 1%) and "minor" (< 1%) constituents. The general classes are described as total saturates (17 fatty acids) for which concentration ranged by depth from 17 to 28%, total monounsaturates (19 fatty acids) from 66%-71% and total polyunsaturates (9 fatty acids) 6% to 12% for the standard blubber sample collected (1 meter caudal to the blowhole on dorsal midline). The nutritional benefit of many fatty acids have become well recognized including many present in the blubber samples and this will be discussed later.

Vitamins (summary by nutrient)
Based on the lipid content of these animal tissues it is not surprising that the lipophilic vitamins are abundant, and the more water soluble vitamins (i.e., vitamin C) are less so. Below we outline our findings and discuss the major human health related issues to the levels of vitamins determined.

Vitamins not directly assayed that would be expected to be found in bowhead whales based on occurrence in other mammals (mostly organ meats) include biotin (liver), choline (liver), niacin (meat), pantothenic acid, riboflavin (B2), vitamin B6 (comprises a group of related compounds including pyridoxal, pyridoxine, pyridoxamine, and 5'-phosphates), and vitamin B12 (cobalamin). We report values for some of these nutrients but did not focus on them for this study. Heller and Scott (1967) analyzed bowhead whale "flesh" and *maktak* and documented 0.19, 0.79, and 7.4 mg/100g and .08, 0.02, and 0.8 mg/100g for thiamine, riboflavin, and niacin, respectively. The class vitamin B is known to be an important nutrient provided by non-traditional foods and of limited supply from marine mammals. For example, thiamine was mostly available from imported foods or vitamin preparations; where riboflavin was adequately provided in meats of local resources and easily supplemented with imported products (Heller and Scott, 1967). Nobman (1993) provided limited data on some B vitamins in various foods, including bowhead whales and reported adequate levels (Table 2).

As expected, the bowhead whale tissues do not contain high concentrations of some essential nutrients. Vitamin C was investigated in Inuit traditional foods and raw *mattak* (epidermis or "skin") of white whale (*Delphinapterus leucas*) and the narwhal (*Monodon monoceros*) were reported as 36 and 32 mg/ 100g. Overall traditional foods only contributed 20% of total vitamin C intake, while 80% was from market food (Fediuk et al., 2002). Levels of vitamin C were approximately 65% of the raw tissue concentration when *mattak* was fermented. It would appear that vitamin C in the diet requires supplementation for northern communities. Levels of vitamin C were low in walrus products (< 1 mg/100g) and would be expected to be low in bowhead whales as well. Heller and Scott (1967) report vitamin C levels below level of detection and they also discussed inadequate vitamin C intake by rural Alaskans (1 to 5 mg). Vitamin C status of subsistence foods and residents of northern latitudes likely requires further investigation.

Vitamin A is a lipophilic group and is a complex mixture that includes provitamin A carotenoids that are dietary precursors of retinol. Thus vitamin A equivalency can be quite complicated to calculate or estimate. In this study we report vitamin A as retinol equivalents (RE). One can also determine the retinol activity equivalents (RAE) = 1 ug retinol, 12 ug β-carotene, 24 ug α-carotene, or 24 ug β-cryptoxanthin. To calculate RAEs from REs of provitamin A carotenoids in foods, one can divide the RE by 2. For preformed vitamin A in foods or supplements and for provitamin A carotenoids in supplements, 1 RE = 1 RAE. Thus the complication in determining vitamin A equivalency precisely is difficult and uncertain without detailed analyses on the many forms of vitamin A. Adequate Vitamin A intake is required for normal vision, gene expression, reproduction, embryonic development and immune function. Typical sources include liver, dairy products, fish, some fruits and vegetables. Vitamin A (as preformed vitamin A) has known adverse effects that include teratological effects, and liver toxicity. The recommended upper limit of daily intake or UL is 3,000 ug/day that is likely to pose no risk of adverse effects and this corresponds to approximately 15-30 g of bowhead liver consumed per day. Individuals with high alcohol intake, preexisting liver disease, hyperlipidemia or severe protein malnutrition may be distinctly susceptible to the adverse effects of excess preformed vitamin A intake.

Vitamin D (calciferol) class was measured by Kenny et al. (2003) and showed that animals which primarily prey on invertebrates had comparatively low blubber vitamin D_3 content (bowhead whales, mean = 4.2 ng/g, and no vitamin D_2). In contrast animals that primarily prey on fish had comparatively high blubber vitamin D_3 content (ringed seal, mean = 746.6 ng/g). One µg calciferol is equal to 40 IU vitamin D and is required to maintain serum calcium and phosphorus concentrations at proper levels. Sources of vitamin D include fish liver oils, flesh of fatty fish, liver and fat from seals, fortified milk products and fortified cereals. Elevated plasma 25 (OH) vitamin D concentrations can cause hypercalcemia and the UL is 50ug/day.

Vitamin E or α –tocopherol includes *RRR*- α -tocopherol, the only form of α -tocopherol that occurs naturally in foods, and the *2R*-stereoisomeric forms of α –tocopherol (*RRR*-, *RSR*-, *RRS*-, and *RSS*- α -tocopherol) that occur in fortified foods and supplements. It does not include the *2S*-stereoisomeric forms of α –tocopherol (*SRR*-, *SSR*-, *SRS*-, and *SSS*- α -tocopherol), also found in fortified foods and supplements. The major function of vitamin E appears to be as a nonspecific chain breaking antioxidant (thus it counters the effects of oxidants). Sources of the vitamin E class include vegetable oils, unprocessed cereal grains, nuts, fruits, vegetables, and meats (including some bowhead whale tissues). There is no evidence of adverse effects from the consumption of vitamin E naturally occurring in foods but this has not been assessed in marine mammal based diets. The UL is 1000 mg/day for vitamin E and adverse effects from vitamin E containing supplements may include hemorrhagic toxicity. The UL for vitamin E applies to any form of α-tocopherol obtained from supplements, fortified foods, or a combination of the two.

Omega-3 polyunsaturated fatty acids (PUFAs) are well known for preventing many disease conditions including diabetes (Storlien et al., 1991), heart disease (Kris-Etherton et al., 2002), and obesity. Subsistence foods include many products abundant in these PUFAs. Many of the fatty acids are considered essential and include some of the omega 3 types (docosapentanoic acid, 22:n3 [DPA], eicosapentaenoic acid, C20:5n-3 [EPA], docosahexaenoic acid, C22:6n-3 [DHA], linolenic acid, gamma –linolenic acid), vaccenic acid, oleic acid, bahenic acid, linoleic acid, arachidonic acid, arachidic acid, n-capric acid, n-caproic acid, caprylic acid, erucic acid, and myristic acid. To date, Wetzel and Reynolds (2003) have identified at least 7

of these 16 essential fatty acids in the blubber of the bowhead whale which is not surprising since some are plant derived (e.g., alpha-linolenic acid, C18:3n-3) and would likely not be present. Previous reports indicate that 15-45% of total fatty acids present were omega-3 PUFAs in fish and marine mammal tissues (Malcolm et al., 1996), and that these may be the only common sources of eicosapentaenoic acid (EPA, 20:5) and docosahexaenoic acid (DHA, 22:6). These fatty acids have been linked with reductions in heart disease in general, and a low incidence of heart disease in Geenland Eskimos (Inuit) and other beneficial effects (Bang et al., 1972, 1976, 1980; Dyerberg et al., 1978, 1989). Kris-Etherton et al. (2002) provides evidence from prospective secondary prevention studies suggesting that EPA and DHA supplementation ranging from 0.5 to 1.8 g/d significantly reduces subsequent cardiac and all-cause mortality. For alpha-linolenic acid, total intakes of about 1.5 to 3 g/d seemed beneficial. The omega-3 fatty acids cannot be produced by humans and these are essential for production of prostaglandins (thromboxanes and prostacyclines) that are anti-thrombogenic (resist clot formation) while the omega-6 tends to be thrombogenic (promote clot formation). The ratio of omega-6 to omega-3 is important to consider as well, and this is being addressed by Wetzel and Reynolds in blubber and other tissues of the bowhead whale. Bjerregaard et al. (2003) postulated that historic incidence of cardiovascular disease among Inuit was not lower compared to other western populations. Even if this proved true it does not alter the fact that many fatty acids are important for preventing certain cardiovascular diseases and other diseases in humans that appear to be dramatically rising in prevalence in northern communities.

The omega-3 fatty acids are essential for proper fetal and neonatal development of the nervous system and retina (Martinez et al., 1988; Lanting et al., 1994). Alaskan Yup'ik Eskimo (Inuit) showed a lower risk of diabetes (Adler et al. 1994) when consuming marine (fish and mammal) products yet diabetes is increasing (especially associated with pregnancy) with the introduction and increased use of non-traditional foods (Murphy et al. 1993). Many population health experts in Alaska are aggressively encouraging rural residents to maintain an active and healthy subsistence lifestyle that promotes consumption of these important fatty acids (Egeland et al., 1998). The data provided in this paper supports this vision and philosophy so that individuals can make an informed decision regarding the type of lifestyle they wish to pursue.

CONCLUSION

As expected, the tissues from bowhead whales used as foods are rich in many nutrients especially those considered lipophilic or components of lipids (vitamins A, D, E, PUFAs, etc.). Other nutrients occur at levels that make these tissues excellent sources for humans. Some nutrients are not at adequate levels to maintain human health but a diverse diet, as described for vitamin C by Fediuk et al. (2002), would provide the required balance. The low levels or levels lower than level of detection of some "bad nutrients" (such as cholesterol, trans fatty acids) also indicates an advantage to human health as these have been linked with certain diseases. In conclusion, the bowhead whale provides a valuable source of nutrients to northern communities.

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Table 1. Subadult female bowhead whales epidermis ("skin") nutrient content.

Parameter	Units	RDA	MDL	Pool 1	Pool 2	Pool 3	AVERAGE	SD	% RDA
Calories	/100g	2000	1	115	115	126	*118.7*	*6.35*	5.93
Protein	**g/100g**	**50**	**0.1**	**22.3**	**20.4**	**20.9**	***21.2***	***0.98***	**42.4**
Carbohydrates	g/100g	130g	0.1	4.3	6.2	8.6	*6.37*	*2.15*	4.90
Cholesterol	mg/100g	---	1	246	290	276	*270.67*	*22.48*	
Fat*	g/100g	73	N/A	1	0.9	0.9	*0.93*	*0.06*	1.28
cis-Polyunsaturated Fatty Acids	g/100g	10	N/A	0.1	0.1	0.1	*0.10*	*0.00*	1.00
cis-Monounsaturated Fatty Acids	g/100g		N/A	0.6	0.5	0.5	*0.53*	*0.06*	
Saturated Fatty Acids	g/100g	-	N/A	0.3	0.2	0.3	*0.27*	*0.06*	
Trans-Fatty Acids	g/100g	-	N/A	<0.1	<0.1	<0.1	*0.10*		<MDL
Total Sugars	g/100g	-	0.1	0.1	<0.4	<0.4	*0.10*		At MDL
Total Dietary Fiber	**g/100g**	**20**	**0.1**	**3.2**	**5**	**4.3**	***4.17***	***0.91***	**20.8**
Vitamin A	RE/100g	1000	1	5	7	5	*5.67*	*1.15*	0.57
Retinol**	ug/g						1.65	0.64	
Vitamin C	mg/100g	30	0.1	<0.5	<0.5	<0.5	*0.25*		At MDL
Tocopherol**	**ug/g (ug/100g)**	**15mg**	**-**	**-**	**-**	**-**	**17.2 (1720ug or 1.72 mg)**	**5.98**	**11.5**
Calcium (Ca)	mg/100g	800	0.4	12.5	10	10.1	*10.87*	*1.42*	1.36
Chromium (Cr)	**mg/100g**	**0.125**	**0.05**	**0.07**	**0.06**	**0.08**	***0.07***	***0.01***	**56.0**
Copper (Cu)	mg/100g	1.5	0.04	ND	0.1	0.15	*0.13*	*0.04*	8.33
Iron (Fe)	mg/100g	14	0.06	0.59	0.62	0.76	*0.66*	*0.09*	4.69
Magnesium (Mg)	mg/100g	250	0.03	22.3	22.3	19.8	*21.47*	*1.44*	8.59
Molybdenum (Mo)	**mg/100g**	**0.25**	**0.06**	**0.07**	**ND**	**0.06**	***0.07***	***0.01***	**26.0**
Phosphorus Total (P)	**mg/100g**	**800**	**0.4**	**185**	**202**	**190**	***192.3***	***8.74***	**24.0**
Potassium (K)	**mg/100g**	**2,000mg**	**10**	**316**	**349**	**324**	***329.7***	***17.2***	**16.5**
Sodium (Na)	**mg/100g**	**500mg**	**0.9**	**77.6**	**84.9**	**77.1**	***79.9***	***4.37***	**16.0**
Zinc (Zn)	**mg/100g**	**15**	**0.03**	**1.83**	**1.74**	**1.65**	***1.74***	***0.09***	**11.6**

Pool 1: 97B31, 97B30, 98B24, 97B25 Liver, Blubber, Epidermis, Kidney, Muscle
Pool 2: 97B19, 97B14, 97B24, 98B11 Liver, Blubber, Epidermis, Kidney, Muscle
Pool 3: 97B22, 98B12, 97B21, 98B10 Liver, Blubber, Epidermis
ND = Not detected, N/A = Not Applicable, MDL = method detection limit
Bold text >10% RDA met by 100g or 3 ounce serving
*Recommended Maximum Fat Intake for 2000 cal diet
**Rosa and Mazzaro, pers comm. (vitamin E)

Table 2. Subadult female bowhead whales skeletal muscle (lumbar) nutrient content.

Parameter	Units	RDA	MDL	Pool 1	Pool 2	AVERAGE	% RDA
Calories	/100g	2000	1	118	111	*114.50*	5.73
Kcal (Nobmann)						*177*	
Protein (Nobmann)	**g/100g**	**50**	**0.1**	**22.7**	**22**	***22.4 (26.2)***	**44.7 (52.4)**
Carbohydrates	g/100g	130g	0.1	3.2	3	*3.10*	2.4
Cholesterol	mg/100g	NA	1	59	58	*58.5*	
Cholesterol						*28*	
Fat*	g/100g	73	N/A	1.6	1.2	*1.40*	1.92
Lipid (Nobmann)						*46.1*	
cis-Polyunsaturated Fatty Acids	g/100g	10	N/A	0.4	0.2	*0.30*	3.00
Polyunsaturated (Nobmann)	**g/100g**	**10**				***1.11***	**11.1**
18:2 (Nobmann)						*.05*	
18:3 (Nobmann)						*.07*	
cis-Monounsaturated Fatty Acids	g/100g		N/A	0.7	0.5	*0.60*	
Monounsaturated (Nobmann)						*3.43*	
Saturated Fatty Acid (Nobmann)	g/100g	ND	N/A	0.4	0.4	*0.40 (1.22)*	
Total Sugars	g/100g		0.1	0.4	0.5	*0.45*	
Total Dietary Fiber	g/100g	20	0.1	1.4	0.8	*1.10*	5.50
Vitamin A	RE/100g	1000	1	<1	<1	*<1*	<0.10
Vitamin C	mg/100g	30	0.1	<0.5	<0.5	*0.25*	0.83
Riboflavin	**mg/100g**	**1.3**				***0.79* (Nobmann)**	**60.8**
Thiamine	**mg/100g**	**1.2**				***0.19* (Nobmann)**	**15.8**
Niacin	**mg/100g**	**16**				***7.4* (Nobmann)**	**46.3**
Calcium (Ca)	mg/100g	800	0.4	3.5	4.1	*3.80*	0.48
Copper (Cu)	mg/100g	1.5	0.04	0.08	0.1	*0.09*	6.00
Iron (Fe) (Nobmann)	**mg/100g**	**14**	**0.06**	**16.9**	**14.2**	***15.6 (14.1)***	**111.1 (100.7)**
Magnesium (Mg)	**mg/100g**	**250**	**0.03**	**27.3**	**26.4**	***26.9***	**10.7**
Molybdenum (Mo)	**mg/100g**	**0.25**	**0.06**	**0.08**	**ND**	***0.08***	**32.0**
Phosphorus Total (P)	**mg/100g**	**800**	**0.4**	**211**	**200**	***205.5***	**25.7**
Potassium (K)	**mg/100g**	**2000**	**10**	**272**	**281**	***276.5***	**13.8**
Sodium (Na)	**mg/100g**	**500**	**0.9**	**37.6**	**50.8**	***44.2***	**88.4**
Zinc (Zn)	**mg/100g**	**15**	**0.03**	**3.88**	**4.18**	***4.03***	**26.9**

Pool 1: 97B31, 97B30, 98B24, 97B25 Liver, Blubber, Epidermis, Kidney, Muscle
Pool 2: 97B19, 97B14, 97B24, 98B11 Liver, Blubber, Epidermis, Kidney, Muscle
ND = Not detected, N/A = Not Applicable, MDL = method detection limit
Bold text >10% RDA met by 100g serving, (Nobmann) = Nobmann, 1993, and Heller and Scott, 1967 tissue described as “flesh”. *Recommended Max Fat Intake for 2000 cal diet

Table 3. Subadult female bowhead whales liver nutrient content.

Parameter	Units	***RDA***	MDL	Pool 1	Pool 2	Pool 3	***AVERAGE***	***SD***	**% RDA**
Calories	/100g	2000	1	104	114	111	*109.67*	*5.13*	5.48
Protein	**g/100g**	**50**	**0.1**	**18**	**18.4**	**17.3**	***17.90***	***0.56***	**35.8**
Carbohydrates	g/100g	130	0.1	2.3	3.4	3.2	*2.97*	*0.59*	2.3
Cholesterol	mg/100g	----	1	307	405	378	*363.3*	*50.6*	-
Fat	g/100g	73	N/A	2.5	3	3.2	*2.90*	*0.36*	3.97
cis-Polyunsaturated Fatty Acids	g/100g	10	N/A	0.6	0.7	0.8	*0.70*	*0.10*	7.00
cis-Monounsaturated Fatty Acids	g/100g		N/A	0.8	0.9	1	*0.90*	*0.10*	
Saturated Fatty Acids (bad)	g/100g	ND	N/A	1	1.2	1.2	*1.13*	*0.12*	
Trans-Fatty Acids (bad)	g/100g	ND	N/A	<0.1	<0.1	<0.1	*<0.1*		
Total Sugars	g/100g		0.1	1.2	1.7	1.6	*1.50*	*0.26*	
Total Dietary Fibre	g/100g	20	0.1	0.9	1	0.8	*0.90*	*0.10*	4.50
Vitamin A	**RE/100g**	**1000**	**1**	**27200**	**20300**	**17100**	***21533.3***	***5161.7***	**2153.3**
Vitamin C	mg/100g	30	0.1	<0.5	<0.5	<0.5	*<0.5*		<1.7
vitamin E**	ug/g (ug/100g)	15mg					772.6 (77260 ug/100g)	1337.9	515.1
Calcium (Ca)	mg/100g	800	0.4	4.8	5.2	5.3	*5.10*	*0.26*	0.64
Chromium (Cr)	**mg/100g**	**0.125**	**0.05**	**0.05**	**0.1**	**0.18**	***0.11***	***0.07***	**88.0**
Copper (Cu)	**mg/100g**	**1.5**	**0.04**	**0.37**	**0.53**	**0.48**	***0.46***	***0.08***	**30.7**
Iron (Fe)	**mg/100g**	**14**	**0.06**	**24.7**	**23.4**	**12.5**	***20.2***	***6.70***	**144.3**
Magnesium (Mg)	mg/100g	250	0.03	13.4	15.8	14.5	*14.6*	*1.20*	5.83
Molybdenum (Mo)	**mg/100g**	**0.25**	**0.06**	**0.08**	**0.13**	**0.23**	***0.15***	***0.08***	**58.7**
Phosphorus Total (P)	**mg/100g**	**800**	**0.4**	**197**	**218**	**192**	***202.3***	***13.8***	**25.3**
Potassium (K)	**mg/100g**	**2000**	**10**	**199**	**247**	**225**	***223.7***	***24.0***	**11.2**
Sodium (Na)	**mg/100g**	**500**	**0.9**	**166**	**140**	**174**	***160.0***	***17.8***	**32.0**
Zinc (Zn)	**mg/100g**	**15**	**0.03**	**2.62**	**3.06**	**2.82**	***2.83***	***0.22***	**18.9**

Maktak estimate based on % of blubber and epidermis by weight
Pool 1: 97B31, 97B30, 98B24, 97B25 Liver, Blubber, Epidermis, Kidney, Muscle
Pool 2: 97B19, 97B14, 97B24, 98B11 Liver, Blubber, Epidermis, Kidney, Muscle
Pool 3: 97B22, 98B12, 97B21, 98B10 Liver, Blubber, Epidermis
Bold text >10% RDA met by 100g serving, ND = Not detected
N/A = Not Applicable
MDL = method detection limit
*Recommended Maximum Fat Intake for 2000 cal diet
**Rosa and Mazzaro pers comm

Table 4. Subadult female bowhead whales kidney nutrient content.

Parameter	Units	***RDA***	MDL	Pool 1	Pool 2	***AVERAGE***	**% RDA**
Calories	/100g	2000	1	178	100	*139.0*	6.95
Protein	**g/100g**	**50**	**0.1**	**13.4**	**14.7**	***14.1***	**28.1**
Carbohydrates	g/100g	130	0.1	3.5	1.8	*2.65*	2.0
Cholesterol	mg/100g	------	1	249	300	*274.5*	
Fat*	**g/100g**	**73**	**N/A**	**12.3**	**3.8**	***8.05***	**11.0**
cis-Polyunsaturated Fatty Acids	**g/100g**	**10**	**N/A**	**2.4**	**0.8**	***1.60***	**16.0**
cis-Monounsaturated Fatty Acids	g/100g		N/A	5.4	1.5	*3.45*	
Saturated Fatty Acids	g/100g	ND	N/A	3.4	1.1	*2.25*	
Trans-Fatty Acids	g/100g	ND	N/A	0.5	0.1	*0.30*	
Total Sugars	g/100g		0.1	<0.4	<0.4	*0.25*	At MDL
Total Dietary Fiber	g/100g	20	0.1	0.4	0.7	*0.55*	2.75
Vitamin A	RE/100g	1000	1	117	48.9	*83.0*	8.30
Vitamin C	mg/100g	30	0.1	<0.5	<0.5	<0.5	<1.66
Calcium (Ca)	mg/100g	800	0.4	10.3	10.5	*10.4*	1.30
Chromium (Cr)	**mg/100g**	**0.125**	**0.05**	**0.09**	**0.13**	***0.11***	**88.0**
Copper (Cu)	**mg/100g**	**1.5**	**0.04**	**0.26**	**0.38**	***0.32***	**21.3**
Iron (Fe)	**mg/100g**	**14**	**0.06**	**4.12**	**6.39**	***5.26***	**37.5**
Magnesium (Mg)	mg/100g	250	0.03	9.89	11.5	*10.70*	4.28
Molybdenum (Mo)	**mg/100g**	**0.25**	**0.06**	**0.08**	**0.13**	***0.11***	**42.0**
Phosphorus Total (P)	**mg/100g**	**800**	**0.4**	**111**	**136**	***123.5***	**15.4**
Potassium (K)	mg/100g	2000	10	132	159	*145.5*	7.3
Sodium (Na)	**mg/100g**	**500**	**0.9**	**210**	**258**	***234.0***	**46.8**
Zinc (Zn)	**mg/100g**	**15**	**0.03**	**1.57**	**2.35**	***1.96***	**13.1**

Maktak estimate based on % of blubber and epidermis by weight
Pool 1: 97B31, 97B30, 98B24, 97B25 Liver, Blubber, Epidermis, Kidney, Muscle
Pool 2: 97B19, 97B14, 97B24, 98B11 Liver, Blubber, Epidermis, Kidney, Muscle
Pool 3: 97B22, 98B12, 97B21, 98B10 Liver, Blubber, Epidermis
ND = Not detected, **Bold text** >10% RDA met by 100g serving
N/A = Not Applicable
MDL = method detection limit
*Recommended Maximum Fat Intake for 2000 cal diet

Table 5. Subadult female bowhead whale heart, tongue, and intestine nutrient content.

Parameter	Units	RDA	heart	%RDA heart	Tongue	%RDA Tongue	Intestine	%RDA Intestine	MDL
Moisture	g/100g	N/A	77	N/A	26	N/A	79.5	N/A	0.1
Fat	g/100g	73	0.9	1.23	**60**	**82.2**	0.6	0.82	0.1
Saturated Fatty Acids	g/100g	ND	0.3	N/A	8.1	N/A	0.2	N/A	0.01
Trans-Fatty Acids	g/100g	ND	<0.1	N/A	3.1	N/A	<0.1	N/A	0.01
cis-Polyunsaturated Fatty Acids	g/100g	10	0.3	3	**16.1**	**161**	0.1	1	0.01
Omega-3 Polyunsaturated Fatty Acids	g/100g	N/A	0.2	N/A	14.3	N/A	0.1	N/A	0.01
Omega-6 Polyunsaturated Fatty Acids	g/100g	N/A	0.1	N/A	1.8	N/A	<0.1	N/A	0.01
cis-Monounsaturated Fatty Acids	g/100g	N/A	0.3	N/A	29.9	N/A	0.2	N/A	0.01
Protein	g/100g	**50**	**20**	**40**	**13.5**	**27**	**18.7**	**37.4**	0.1
Ash	g/100g	N/A	1.1	N/A	0.5	N/A	1	N/A	0.1
Carbohydrates	g/100g	130	1	<1%	<0.1	<1%	0.2	<1%	0.1
Calories	/100g	2000	92.1	4.6	**594**	**29.7**	81	4.05	1
KJ	/100g		390		2490	N/A	340	N/A	1
Cholesterol	mg/100g	NA	193	N/A	79	N/A	269	N/A	1
Total Sugars	g/100g	N/A	0.8	N/A	<0.4	N/A	<0.4	N/A	0.4
Vitamin A	RE/100g	1000	<1	N/A	**164**	**16.4**	38	3.8	1
Chromium (Cr)	mg/100g	0.125	ND	N/A	0.1	80	ND	N/A	0.05
Copper (Cu)	mg/100g	1.5	**0.16**	**10. 7**	**0.21**	**14**	**0.22**	**14. 7**	0.04
Iron (Fe)	mg/100g	14	**8.08**	**57.7**	**4.97**	**35.5**	**1.47**	**10.5**	0.06
Magnesium (Mg)	mg/100g	250	23	9.2	3.84	1.54	10.5	4.2	0.03
Manganese (Mn)	mg/100g	N/A	0.026	N/A	ND	N/A	0.024	N/A	0.015
Phosphorus Total (P)	mg/100g	800	**171**	**21.4**	27.2	3.4	**138**	**17.3**	0.4
Potassium (K)	mg/100g	2000	**319**	**16.0**	54	2.7	**240**	**12.0**	10
Sodium (Na)	mg/100g	500	**131**	**26.2**	**99.5**	**19.9**	**192**	**38.4**	0.9
Zinc (Zn)	mg/100g	15	**3.56**	**23.7**	0.69	4.6	**2.33**	**15.5**	0.03
Calcium (Ca)	mg/100g	800	7.4	0.93	5.8	0.73	11.4	1.43	0.4

Table 6. Subadult female bowhead whale blubber and *maktak* nutrient content.

Parameter	Units	***RDA***	MDL	Pool 1	Pool 2	Pool 3	***SD***	***AVERAGE***	**% RDA blubber**	*maktak*	**% RDA *maktak***
Calories (Nobmann)	**/100g**	**2000**	**1**	**725**	**770**	**788**	***431.6***	***761 (870)***	**38.1**	**439.8**	**22.0**
Protein	**g/100g**	**50**	**0.1**	**7.4**	**2.5**	**5.6**	***3.72***	***5.17***	**10.3**	**13.2**	**26.4**
Carbohydrates (Nobmann)	g/100g	130	0.1	10.4	3.4	0.6	*5.26*	*4.80*	3.7	5.58 (1.2)	
Cholesterol (Nobmann)	mg/100g	------	1	51	61	56	*32.2*	*56.0 (150)*		163 (54)	
Fat (Nobmann)	**g/100g**	**73**	**N/A**	**72.6**	**82.9**	**84.8**	***7.28***	***80 (96.5)***	**109.7**	**41 (46)**	**55.5**
cis-Polyunsaturated Fatty Acids	**g/100g**	**10**	**N/A**	**17.7**	**18.1**	**21**	***0.28***	***18.9***	**189.3**	**9.52**	**95.2**
cis-Monounsaturated Fatty Acids (Nobmann)	g/100g		N/A	34.6	41.2	40.2	*4.67*	*38.7*		19.6 (28.1)	
Saturated Fatty Acids (Nobmann)	g/100g	ND	N/A	13.3	15.4	15.7	*1.48*	*14.8*		7.53 (6.56)	
Trans-Fatty Acids	g/100g	ND	N/A	3.8	4.5	4.3	*0.49*	*4.20*		2.15	
Total Sugars	g/100g		0.1	<0.4	<0.4	<0.4		*0.40*		0.25	
Total Dietary Fiber	g/100g	20	0.1	0.7	2.8	0.5	*1.42*	*1.33*	6.67	**2.75**	**13.8**
Vitamin A	RE/100g	1000	1	111	39.7	84.1	*55.8*	*78.3*	7.83	42.0	4.20
Vitamin C	mg/100g	30	0.1	<0.5	<0.5	<0.5		*0.25*	0.83	0.25	0.83
Vitamin D	ug/100g	5 ug					*1.1*	*4.2ng/g 420ng/100g 0.42ug/100g*	8.4		
Vitamin E		15mg						9.20 ug/g *920ug/100g 0.92mg/100g*	6.1		
Riboflavin (Nobmann)	mg/100g	1.3								.02	1.5
Thiamine (Nobmann)	mg/100g	1.2								.08	6.7
Calcium (Ca)	mg/100g	800	0.4	1.8	2	2.1	*0.87*	*1.97*	0.25	6.42	0.80
Chromium (Cr)	**mg/100g**	**0.125**	**0.05**	**0.07**	**0.07**	**0.09**	***0.01***	***0.08***	**61.3**	**0.07**	**58.7**
Copper (Cu)	**mg/100g**	**1.5**	**0.04**	**1.82**	**0.15**	**ND**	***1.00***	***0.99***	**65.7**	**0.56**	**37.0**
Iron (Fe) (Nobmann)	mg/100g	14	0.06	0.23	0.23	0.49	*0.10*	*0.32 (0.5)*	2.26	0.49	3.48
Magnesium (Mg)	mg/100g	250	0.03	0.58	0.8	0.86	*0.40*	*0.75*	0.30	11.1	4.44
Molybdenum (Mo)	**mg/100g**	**0.25**	**0.06**	**ND**	**0.09**	**0.11**	***0.02***	***0.10***	**40.0**	**0.08**	**33.0**
Phosphorus Total (P)	mg/100g	800	0.4	6.1	8.5	7.7	*4.16*	*7.43*	**0.93**	**99.9**	**12.5**
Potassium (K)	mg/100g	2000	10	ND	14	15	*2.83*	*14.5*	0.7	172.1	8.6
Sodium (Na)	mg/100g	500	0.9	19.4	25.9	29.1	*13.0*	*24.8*	5.0	**52.3**	**10.5**
Zinc (Zn)	mg/100g	15	0.03	0.18	0.23	0.26	*0.10*	*0.22*	1.49	0.98	6.54

Maktak estimate based on % of blubber and epidermis by weight
Pool 1: 97B31, 97B30, 98B24, 97B25 Liver, Blubber, Epidermis, Kidney, Muscle
Pool 2: 97B19, 97B14, 97B24, 98B11 Liver, Blubber, Epidermis, Kidney, Muscle
Pool 3: 97B22, 98B12, 97B21, 98B10 Liver, Blubber, Epidermis
ND = Not detected, (Nobmann) = reported by Nobmann, 1993, and Heller and Scott, 1967
N/A = Not Applicable, Vitamin D as cholecalciferol.
MDL = method detection limit
*Recommended Max Fat Intake for 2000 cal diet

Components not detected in the 3 tissue types are not reported in the Table.

Table 7. Bowhead whale 98B23 percent composition of major and minor individual fatty acids in blubber collected approximately 1 meter caudal to the blowhole (BD) at varying depths (1=outer, 5 = most inner).

Major	**BD2**	**BD3**	**BD4**	**BD5**
16:1n7c	32.11%	24.23%	29.34%	27.10%
18:1n9	16.39%	21.19%	16.28%	21.10%
16:0	7.25%	13.67%	15.74%	12.85%
18:1n7	6.97%	9.91%	7.33%	11.41%
14:0	5.53%	4.73%	6.37%	4.67%
20:5n3	4.91%	7.44%	4.76%	6.02%
18:1n11	4.30%	3.62%	3.37%	3.44%
20:1n9	3.09%	5.09%	5.13%	5.99%
16:2n4	1.50%	0.86%	ND	ND
22:6n3	1.49%	ND	0.88%	ND
22:1n11	1.29%	0.31%	0.08%	ND
14:1n5	1.10%	0.38%	0.30%	ND
Minor	**BD2**	**BD3**	**BD4**	**BD5**
22:5n3	0.73%	ND	0.70%	ND
20:1n11	0.72%	0.98%	0.94%	0.53%
20:1n7	0.67%	1.05%	1.10%	1.86%
18:0	0.62%	1.78%	1.91%	1.80%
3,7,11,15-4 me-20	0.55%	1.56%	1.85%	2.36%
22:1n9	0.44%	1.15%	1.56%	ND
17:1n8	0.33%	0.46%	0.40%	ND
18:1n5	0.28%	0.60%	0.52%	ND
15:0	0.23%	0.27%	0.35%	0.27%
16:1n5	0.21%	0.51%	ND	ND
12:0	0.15%	0.06%	0.10%	0.61%
iso_15	0.13%	0.16%	0.26%	ND
15:1n7	0.07%	ND	0.07%	ND
Anteiso 15	0.04%	ND	0.06%	ND
Total Saturates	**17.87%**	**22.23%**	**27.25%**	**22.56%**
Total Monounsaturates	**69.75%**	**69.47%**	**66.41%**	**71.42%**
Total Polyunsaturates	**12.37%**	**8.30%**	**6.34%**	**6.02%**

*Fatty acid detected at another site for blubber collection 14:1n7, 13:0, 21:5n3, 22:1n7, Anteiso 17, and Iso 17. Table from Wetzel and Reynolds, 2003. ND = not detected.
Fatty acids detected in BD2 but not other depths include anteiso_18, 16:3n4, 16:1n11, 16:4n1, 18:4 n3, 16:1n9, 9-Me- 20:0, 10-me 22:0, 4,8,12-3me16, 20:4n6, and 15:1n6. Fatty acids 2,6,10,14-4-me-19:0 and 17:0 were detected in layer BD4 only.