POLAR BEAR NUTRITION GUIDELINES

Authors
B.A. Lintzenich, M.S., Cincinnati Zoo & Botanical Garden
A.M. Ward, M.S., Fort Worth Zoo
M.S. Edwards, Ph.D., Smithsonian National Zoological Park
M.E. Griffin, Ph.D., Purina Mills, Inc.
C.T. Robbins, Ph.D., Washington State University

Sponsored by

Polar Bears International
AZA Bear TAG
# TABLE OF CONTENTS

1. EXECUTIVE SUMMARY 5

2. FEEDING ECOLOGY AND GI MORPHOLOGY 5

3. TARGET NUTRIENT VALUES 6  
   a. Justification 6  
   b. Energy 6  
   c. Protein 7  
   d. Fat 7  
   e. Carbohydrates 8  
   f. Vitamins 8  
   g. Minerals 9  
   h. Water 9  
   i. Cat and dog nutrient profile 10

4. CAPTIVE DIETS 11  
   a. Seasonal changes 11  
   b. Nutritionally complete products available 15  
   c. Food categories and suggested ranges with flexibility for seasonal changes 16  
   d. Sample diets 17  
   e. Presentation and sequence of feeding 18  
   f. Carcass feeding 18  
   g. Browse/Deleterious plant list 18  
   h. Sanitation/food handling 19

5. ASSESSING BODY CONDITION 23  
   a. Standard body scoring of polar bears used by field biologist 23  
   b. Bioelectrical Impedance Analysis (BIA) 23

6. SERUM NUTRIENT NORMS 25

7. ASSESSING STOOL CONDITION 27

8. HAND REARING 28  
   a. Background 28  
   b. Milk composition 28  
   c. Formula selection 29  
   d. Feeding /intake 33  
   e. Weaning 40

9. APPENDICES 41  
   a. Age classification 41  
   b. Example diets that meet suggested ranges 42  
   c. Specifications for appropriate nutritionally complete foods 43  
   d. Specification for appropriate nutritionally complete meat mix 44  
   e. Behavioral Enrichment 45
f. Checklist for inspecting a meat/prey or fish shipment 45

g. Quality control meat/prey standards 46

h. Quality control fish standards 47

i. Feeding Schedule/Interval taken from a survey conducted by Celia Ackerman 48

j. Selected food products used taken from a survey conducted by Celia Ackerman 49

k. From Husbandry and pathology of polar bears in Swiss Zoos 49

l. Results on nutrition of the European polar bear survey 1999 50

m. Meat consumption by three adult polar bears at Cologne zoo in 1991 51

n. Summary of the AZA Bear TAG survey results from 1996-2001 52

o. Areas of historical controversy 56

ii. Thiamin and vitamin E supplementation 56

iii. Salt 57

iv. Vitamin D and calcium 57

v. Fat 57

vi. Dental issues 58

vii. Salmonid Poisoning and Tapeworms 58

p. Partial list of references on plants that may be deleterious to various animal species 60

10. LITERATURE CITED 60

11. ADDITIONAL WORK PLANNED 65

12. RESEARCH 65
Foreword

The authors would like to take this opportunity to thank Polar Bears International (PBI) for making it possible for this document to be accomplished. In January of 2004 at the International Polar Bear Husbandry Conference in San Diego California, it became apparent that polar bear nutrition guidelines were needed. While many gaps in our knowledge base on polar bear nutrition exist, this document includes a review of the literature as well as documented feeding experience to date. At that time PBI offered to help the Bear Taxon Advisory Group (TAG) and the Polar Bear Species Survival Plan (SSP) with whatever means were needed to allow polar bear guidelines to be produced. A group of nutritionists, managers, keepers, and veterinarians meet four times over a period of a year to outline all questions and areas of concern. The five nutritionists on this group then were able to compile the following guidelines. PBI supported and facilitated these meetings as well as publication of this document. The authors also would like to thank the reviewers Barbara Toddes and Jan Dempsey.

Special Thanks

We would like to acknowledge the hard work of the following individuals who participated in the various workshops over a twelve month period. Without their energy and determination this document would not have been possible. Celia Ackerman
Mike Briggs, DVM, MS
Robert & Carolyn Buchanan
Darin Collins, DVM Amy Cutting
Mark Edwards, PhD Mark Griffin, PhD
Lydia Kolter, PhD
Barbara Lintzenich, MS
Randi Meyerson Dinon, DVM
Don Moore, PhD Else Poulsen
Holly Reed, DVM
Charles T. Robbins, PhD
JoAnne Simerson
Danny Skirvin
Ann Ward, MS
Diana Weinhardt
POLAR BEAR NUTRITION GUIDELINES

Authors:
B.A. Lintzenich, M.S., Cincinnati Zoo & Botanical Garden
A.M. Ward, M.S., Fort Worth Zoo
M.S. Edwards, Ph.D., Smithsonian National Zoological Park
C.T. Robbins, Ph.D., Washington State University
M.E. Griffin, Ph.D., Purina Mills, Inc.

Contributors:
K.A. Slifka, M.S., Brookfield Zoo – Handrearing section
K. Jacobsen, M.S. – Handrearing section contributed while working at Brookfield Zoo

1. EXECUTIVE SUMMARY
Polar bears, the most carnivorous of the Ursidae family, prey primarily on ringed seals (Best, 1985; Derocher, et. al, 2000; Stirling and Archibald, 1977). When brought into captivity, maintaining their nutritional and mental health can be challenging. Due to the lack of in-depth species-specific research, captive polar bear diets must be based on a combination of known requirements of related domestic animals, the successful captive polar bear diets, and nutrients consumed by healthy captive polar bears to formulate dietary recommendations. A balanced diet for captive bears could include a combination of nutritionally complete items (dry, raw, and/or gel), saltwater fish, bones, whole prey, produce, and enrichment food items. All bears should be offered a diet that would maintain appropriate body condition across all seasons.


2. FEEDING ECOLOGY AND GI MORPHOLOGY
Polar bears, the most carnivorous of the Ursidae family, prey primarily on ringed seals (Best, 1985; Derocher, et. al, 2000; Stirling and Archibald, 1977). Other seals (bearded and harp), some whales (white and narwhal), walrus, reindeer, sea birds, carrion, and vegetation are consumed (Derocher, et. al, 2000; Derocher, et. al, 2002; Knudson, 1978; Russel, 1975; Smith and Sjare, 1990). Consumption varies depending on the season and location. Some high arctic bears prey on seals year-round (Derocher et. al, 2002). In locations where ice recedes and bears are restricted to land for up to 6 months, seasonal adaptations may include fasting or very limited food intake (Knudsen, 1978). Though bears prefer the energy rich blubber of seals, whole carcasses still contribute to the overall diet and may be especially important to subadults and orphaned cubs (Stirling, 1974).
The stomach of Ursidae is simple, a cecum is absent, and there is no obvious external differentiation between small and large intestine (Stevens and Hume, 1995). Similar to other carnivores, polar bears efficiently digest protein and fat (Best, 1985). Their simple digestive tract is well suited for their meat diet.

3. TARGET NUTRIENT VALUES

a. Justification
Due to the lack of species-specific data, it is reasonable to consider the known requirements of related domestic animals. Domestic models have been studied in great detail, and thus provide a database from which to extrapolate. A range of probable requirements can be established for polar bears based on animals with similar feeding ecology, and gastrointestinal tracts. Domestic cats and dogs are used as models for polar bears (NRC, 2006; AAFCO 2004). Cats are considered strict carnivores and dogs omnivores. Polar bears are primarily carnivorous but occasionally consume plant matter (Knudson, 1978; Russel, 1975). Captive polar bears will readily consume plant matter. Consequently a range of nutrient levels encompassing both feeding strategies is appropriate for formulation of captive polar bear diets (see table 1).

b. Energy
Energy is required by the body for growth, maintenance, reproduction and work (Case et al, 2000; NRC 2006). Energy functions include maintaining and synthesizing body tissues, engaging in physical work, and regulating normal body temperature (Case, 1999). Approximately, 50-80% of the dry matter of a dog or cat’s diet is used for energy (Case et al, 2000). Energy of foods can be directly measured by calorimetry and typically provided in kilocalories. Gross energy (GE) is the process of complete combustion (oxidation) of a pre-measured amount of food in a bomb calorimeter, resulting in a release and measurement of the food’s total chemical energy (Case et al, 2000). Animals can’t utilize all of the food’s gross energy because of losses during digestion and metabolism. Digestible energy (DE) is the amount of energy absorbed across the intestine. Metabolizable energy (ME) is the amount of energy available after losses in the feces and urine have been counted. Metabolizable energy requirements for adult dogs are between 130-200 kcal/kg body mass\(^{0.75}\) (NRC 2006). Metabolizable energy requirements for exotic cats (seven species of non-domestic cats ranging in size from 4 to 138 kg) range from 55 to 260 kcsals/kg body mass\(^{0.75}\) (NRC 2006). The metabolizable energy requirement for free-ranging polar bears has been estimated at 140-182 kcal/kg \(^{0.75}\) (Best, 1985). Additionally, Best (1985) reported captive bears consumed 110 kcal ME/kg \(^{0.75}\) (on a DE basis 115 kcals DE/kg \(^{0.75}\)), which is lower than that reported for large cats).

Structural growth of female polar bears is completed by 5 years, but body mass in adults fluctuates depending on season and reproductive status (Atkinson and Ramsey, 1995). Polar bears are unusual among large mammals for their extreme body weight fluctuations between periods of hyperphagia (gorging) and winter dormancy. Polar bears seasonally exhibit wide variation in body fat, lean body mass (LBM), and thus nutritional condition depending on the time of the year (Cattet, 1990). Depending on location, some bears fast minimally (limited “ice free” season) or for greater periods. Pregnant/lactating females at lower latitudes that
must retreat to land during an “ice free” season and then subsequently must den during the early months of cub production may fast for up to 8 months. The ability of polar bears to endure prolonged fasting depends on the accumulation or replenishment of fat and LBM during the active phase of the year (Atkinson et. al., 1996, Atkinson and Ramsay, 1995). These authors concluded polar bears are no more efficient in minimizing protein catabolism during a fast than brown or black bears, but that the proportion of lean body mass lost during the fast depends on the amount of fat available at the start of hibernation.

c. Protein
Proteins are made up of amino acids and can range from a few amino acids to extremely large molecules. Proteins are the major structural components of hair, feathers, skin, nails, tendons, muscles, bones, ligaments, and cartilage (Case et al, 2000; NRC 2006). Additionally, soluble proteins occur throughout the body as enzymes and hormones and as carriers or transporters of other nutrients or metabolites in blood and tissues (Case 1999). The body’s immune system is primarily protein as antibodies or cells (Case, 1999).

Amino acid concentrations provided in commercial diets sustain normal growth and reproduction (NRC, 2006). Cats have a higher protein requirement than dogs and do not adapt well on low protein diets (NRC, 2006). Cats have evolved differently due the inability to down regulate enzymes and utilize carbohydrate. They will continue to lose protein via nitrogen when food is restricted or on low protein diets. There are ten essential amino acids required in the diets of domestic dogs and cats. Additionally, taurine is an essential dietary nutrient for cats (NRC, 2006).

Many polar bears consume predominately the blubber of seals or the whole seal if small (Best, 1985; Derocher, et. al, 2000; Stirling and Archibald, 1977). The meat and skin or the whole seal carcass is more often consumed by pregnant females with cubs and sub-adults. During these life stages, protein requirements are increased. Thus, more extensive carcass consumption may be the method for meeting these increased protein needs (Atkinson and Ramsey, 1995; Atkinson et al, 1996). Amino acid composition for seal meat was similar to beef except that seal meat had lower sulfur-containing AA and higher histidine (Hoppener et al, 1978). Minimal protein requirements for maintenance of lean body mass in brown bears for brief periods of time in hyperphagia are as low as 5% protein (Felicetti et al. 2003). However, when given access to ad libitum low protein fruit and a purified high quality protein in a cafeteria-type study, brown bears of all ages voluntarily selected a diet containing 12% protein (Robbins, unpublished).

d. Fat
Fat has two primary roles: to provide a high-density source of energy and to supply essential fatty acids (NRC, 2006). Essential fatty acids are structurally important in cell membranes, regulate cell function, and are carriers of fat soluble vitamins (Case et al, 2000).

Dogs and cats require 3 essential fatty acids: linoleic (18:2), gamma-linolenic (18:3), and arachidonic (20:4) acid (Case, 1999). Dogs can synthesize the 18:3 and 20:4 from linoleic acid. Thus, dogs have only one dietary essential fatty acid (linoleic acid). Cats, however,
cannot synthesize all sufficient arachidonic acid for all physiological states and must consume all three essential fatty acids (Case et al, 2000).

Polar bears feeding predominately on seals consume large quantities of fat. The resulting extreme obesity in pregnant females is required to meet their energy needs for up to 8 months of fasting. In non-denning animals, less extreme obesity occurs but is still necessary for the fasting period when ice has receded and food is limited. Body condition of male polar bears declined when coming ashore and ranged from 0.12 to 0.58 kg of fat/kg LBM at initial capture (Atkinson et al, 1996). Over the 66-88 days of fasting, males lost between 42-121 kg of body mass. Of this loss 12-72 kg was fat, while 4-78 kg was LBM. Between 74% and 99% of the loss in body energy was attributed to loss of body fat. Pregnant females were significantly heavier in fat, lean and total body mass, and also were relatively fatter than females with offspring (Atkinson and Ramsey, 1995). The use of fat to meet energy need conserves body protein catabolism and its resulting urea formation/urine output. The formation of urine requires water. For polar bears, water consumption is not energy efficient considering the increase in metabolism needed for the water to warm to body temperature (Nelson, 1983); and freshwater may be limited in a largely in a marine environment.

Captive polar bears had more intra-abdominal adipose than wild bears (Colby et al, 1993). Additionally, the fatty acid composition differed between captive and wild bears with captive bears possessing fewer unsaturated fatty acids (especially hexadecenoic (16:1), eicosanoic (20:1), and docosahexaenoic (22:6) with almost no docosapentaenoic (22:5)) and wild bears having an abundant quantity of 22:5 and 22:6 (Colby et al, 1993). Samples of seal muscle were relatively high in concentrations of long-chained unsaturated fatty acids (Hoppener et al, 1978). Difference in captive and wild bears reflects differences in diets consumed.

e. Carbohydrates
Carbohydrates are the major energy-containing constituents of plants, making up 60-90% of the dry matter weight (Case 1999; Case et al, 2000). Within the body, carbohydrate is used as a source of energy (Case 1999; NRC 2006). When dietary carbohydrate is consumed in excess of the body’s energy needs, most is converted to fat for energy storage (Case 1999). The simple sugar, glucose, is an important energy source for tissues and the proper functioning of the central nervous system. The cat does not encounter a lot of carbohydrate in prey food items and perhaps is less efficient than the dog, which eats a more varied diet, in the utilization of dietary carbohydrate for glucose. There is not a direct requirement in cats and dogs for carbohydrates, but dietary fiber in the form of structural carbohydrates plays a part in normal gastrointestinal health (Case 1999; Case et al, 2000; Clemens, 1996; NRC 2006).

f. Vitamins
Vitamins are organic molecules that are needed in minute amounts to function as coenzymes, cofactors, and metabolic regulators for the body’s metabolic processes (Case 1999; Case et al, 2000; NRC 2006). Vitamins are categorized as fat soluble (A, D, E, K) and water soluble (C and all the B’s). Fat soluble vitamins are digested and absorbed similar to fat with their metabolites excreted in the feces, while water soluble vitamins are absorbed in the small intestine and are excreted in the urine. Vitamins cannot be synthesized in the body and must
be provided in the diet with the exception of vitamin C and perhaps a few B vitamins, (NRC 2006).

Ursid 25-hydroxy vitamin D (25(OH)D) serum values were greater than those of canids (Crissey et al, 2001). Also, the 25(OH)D values for polar bears were the second highest measured and captive polar bear diets met or exceeded probable requirements (Crissey et al, 2001). 25(OH)D values in serum were not different between captive and free-ranging polar bears, both values were three times higher than those reported for humans and dogs (Kenny et al, 1998). Higashi and Senoo (2003) researched the hepatic cells of polar bears and determined that hepatic stellate cells have the capacity for storage of vitamin A. They can store 80% of the total vitamin A in the whole body as retinyl esters in lipid droplets in the cytoplasm, and play pivotal roles in regulation of vitamin A homeostasis. Hoppener (1978) found that ascorbic acid was present in significant amounts in baby seal liver. Baby seal liver contained similar levels of thiamin, riboflavin, vitamin B\textsubscript{12}, folacin, pantothenic acid and less vitamin B\textsubscript{6} than those reported for pork, beef, calf, and lamb liver (Hoppener et al, 1978).

g. Minerals
Minerals are inorganic elements that are essential to normal growth, development, and maintenance of the body (NRC 2006). Only about 4% of the body is comprised of minerals but they are essential for life. Minerals function in the body as components of the skeleton and certain transport proteins and hormones, activate enzymatically catalyzed reactions, aid in nerve transmission and muscle contractions, and function in water and electrolyte balance (Case, 1999).

h. Water
Water is the most important essential nutrient for the body (Case 1999; Case et al, 2000; NRC 2006). Approximately, 70% of lean adult body weight is water and many tissues in the body are composed of 70-90% water (Case 1999; Case et al, 2000). In the body, water functions as a solvent that allows cellular reactions and provides a transport medium for nutrients and waste products (Case, 1999). Water further functions in temperature regulation by absorbing the heat that is generated by the body’s metabolic processes (Case 1999; Case et al, 2000).

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Unit</th>
<th>Minimum Nutrient Profile</th>
<th>Minimum Dietary Recommendations\textsuperscript{b}</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Cat</td>
<td>Dog</td>
</tr>
<tr>
<td>Protein</td>
<td>%</td>
<td>26.0 (30.0)</td>
<td>18.0 (22.0)</td>
</tr>
<tr>
<td>Fat, min</td>
<td>%</td>
<td>9.0</td>
<td>5.0 (8.0)</td>
</tr>
<tr>
<td>Fat, max</td>
<td>%</td>
<td>-</td>
<td>8.0</td>
</tr>
<tr>
<td>Lysine</td>
<td>%</td>
<td>0.83 (1.2)</td>
<td>0.63 (0.77)</td>
</tr>
<tr>
<td>Methionine + Cystine</td>
<td>%</td>
<td>1.1</td>
<td>0.43 (0.53)</td>
</tr>
<tr>
<td>Methionine</td>
<td>%</td>
<td>0.62</td>
<td>-</td>
</tr>
<tr>
<td>Taurine</td>
<td>%</td>
<td>0.1</td>
<td>-</td>
</tr>
<tr>
<td>Linoleic Acid</td>
<td>%</td>
<td>0.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Nutrient</td>
<td>Cat</td>
<td>Dog</td>
<td>Suggested Dietary</td>
</tr>
<tr>
<td>-------------------</td>
<td>-------</td>
<td>-------</td>
<td>-------------------</td>
</tr>
<tr>
<td>Arachidonic</td>
<td>%</td>
<td>0.02</td>
<td>-</td>
</tr>
<tr>
<td>Vitamin A min</td>
<td>IU/g</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Vitamin A max</td>
<td>IU/g</td>
<td>333^{a}</td>
<td>50^{a}</td>
</tr>
<tr>
<td>Vitamin D&lt;sub&gt;3&lt;/sub&gt;</td>
<td>IU/g</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Vitamin E</td>
<td>IU/kg</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>Vitamin K</td>
<td>mg/kg</td>
<td>0.1</td>
<td>-</td>
</tr>
<tr>
<td>Thiamin</td>
<td>mg/kg</td>
<td>5.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Riboflavin</td>
<td>mg/kg</td>
<td>4.0</td>
<td>2.2</td>
</tr>
<tr>
<td>Niacin</td>
<td>mg/kg</td>
<td>60.0</td>
<td>11.4</td>
</tr>
<tr>
<td>Pyridoxine</td>
<td>mg/kg</td>
<td>4.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Folacin</td>
<td>mg/kg</td>
<td>0.8</td>
<td>0.18</td>
</tr>
<tr>
<td>Biotin</td>
<td>mg/kg</td>
<td>0.07</td>
<td>-</td>
</tr>
<tr>
<td>Vitamin B&lt;sub&gt;12&lt;/sub&gt;</td>
<td>mg/kg</td>
<td>0.02</td>
<td>0.022</td>
</tr>
<tr>
<td>Choline</td>
<td>mg/kg</td>
<td>2400</td>
<td>1200</td>
</tr>
<tr>
<td>Calcium</td>
<td>%</td>
<td>0.6 (1.0)</td>
<td>0.6 (1.0)</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>%</td>
<td>0.5 (0.8)</td>
<td>0.5 (0.8)</td>
</tr>
<tr>
<td>Magnesium</td>
<td>%</td>
<td>0.04 (0.08)</td>
<td>0.04 (0.08)</td>
</tr>
<tr>
<td>Potassium</td>
<td>%</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Sodium</td>
<td>%</td>
<td>0.2</td>
<td>0.06 (0.3)</td>
</tr>
<tr>
<td>Iron</td>
<td>mg/kg</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Zinc</td>
<td>mg/kg</td>
<td>75</td>
<td>120</td>
</tr>
<tr>
<td>Copper</td>
<td>mg/kg</td>
<td>5.0 (15.0)</td>
<td>7.3</td>
</tr>
<tr>
<td>Manganese</td>
<td>mg/kg</td>
<td>7.5</td>
<td>5.0</td>
</tr>
<tr>
<td>Iodine</td>
<td>mg/kg</td>
<td>0.35</td>
<td>1.5</td>
</tr>
<tr>
<td>Selenium</td>
<td>mg/kg</td>
<td>0.1</td>
<td>0.11</td>
</tr>
</tbody>
</table>

and dog nutrient profile minimum for all stages compared to suggested dietary
recommendations for polar bears levels on a dry matter basis. Association of American Feed Company Officials (AAFCO) 2004 and National Research Council Nutrient Requirements of Cats and Dogs (NRC) 2006.

\(^{b}\)Values should be adequate for growing cubs
4. CAPTIVE DIETS
a. Seasonal changes: The goal of all diets throughout the seasons is good physical and psychological health and condition. Each institution should assess seasonal diet changes based on the body condition and appetite of their bears. Preliminary consumption data for polar bears across the U.S. in Table 2 below table were collected from 1996-2001 as part of a Bear TAG diet survey or as a part of regular diet analysis. Limited data points make references to intakes based on climate difficult to assess. More in-depth data collections examining intakes and body weight changes across seasons are a priority. Nutrient consumption for these bears is in the appendix 9, section n. For a review of surveys of captive diets in the U.S. and Europe see appendix 9, sections i, j, k, l, m, n.

Table 2. Bear TAG Survey 1996-2000, Oregon data 2001

<table>
<thead>
<tr>
<th>Location</th>
<th>Bears</th>
<th>Zoo</th>
<th>Fall</th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northwest</td>
<td>2</td>
<td>Oregon</td>
<td>1.98</td>
<td>1.49</td>
<td></td>
<td></td>
</tr>
<tr>
<td>North</td>
<td>3</td>
<td>Detroit</td>
<td>1.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Midwest</td>
<td>2</td>
<td>Lincoln Park</td>
<td>3.43</td>
<td>2.56</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Midwest</td>
<td>3</td>
<td>Indianapolis</td>
<td>2.42</td>
<td>1.55</td>
<td></td>
<td></td>
</tr>
<tr>
<td>West</td>
<td>3</td>
<td>San Francisco</td>
<td>1.04</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Southeast</td>
<td>2</td>
<td>North Carolina</td>
<td>1.47</td>
<td>2.42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Southwest</td>
<td>3</td>
<td>Reid Park</td>
<td>2.24</td>
<td>2.79</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Average</td>
<td>2.00</td>
<td>1.81</td>
<td>2.56</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Standard Deviation</td>
<td>0.48</td>
<td>0.90</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Number of Animals</td>
<td>7</td>
<td>10</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Location</th>
<th>Bears</th>
<th>Zoo</th>
<th>Fall</th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northwest</td>
<td>1</td>
<td>Oregon</td>
<td>2.62</td>
<td>2.48</td>
<td></td>
<td></td>
</tr>
<tr>
<td>North</td>
<td>1</td>
<td>Detroit</td>
<td>1.02</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Midwest</td>
<td>1</td>
<td>Lincoln Park</td>
<td>2.79</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Midwest</td>
<td>3</td>
<td>Indianapolis</td>
<td>3.32</td>
<td>3.97</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Southeast</td>
<td>3</td>
<td>North Carolina</td>
<td>3.96</td>
<td>2.87</td>
<td></td>
<td></td>
</tr>
<tr>
<td>South</td>
<td>2</td>
<td>San Antonio</td>
<td>3.95</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Average</td>
<td>2.32</td>
<td>3.71</td>
<td>2.79</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Standard Deviation</td>
<td>1.18</td>
<td>0.69</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Number of Animals</td>
<td>3</td>
<td>6</td>
<td>1</td>
</tr>
</tbody>
</table>
Over a 12 month period, daily food quantities offered and weekly body weights were monitored as part of routine animal care for three female and one male polar bear approximately 3 years old, sub adults, housed in southern California at the San Diego Zoo. Metabolizable energy intake was estimated based on total food mass offered multiplied by the calculated metabolizable energy content of the respective food item (Table 3). Calculated metabolizable energy content was determined based on: a) information provided by the manufacturer for the primary species for which the diet was formulated; b) combined values for ingredient components of foods; or c) actual gross energy content corrected for apparent digestibility and apparent metabolizable energy coefficients of the specific food item.

Food quantities, and subsequently the caloric energy, offered to these individuals were regulated based on weight trends, visual assessment of body condition, and behavior. Root vegetables (e.g., carrots, sweet potatoes, turnips) were offered in addition to these foods as a non-nutritive source of occupational foods and for satiety.

Table 3. Food items and calculated metabolizable energy content (kcal/g) of those foods offered to 3 females and 1 male captive sub adult polar bears over a twelve-month period at the San Diego Zoo.

<table>
<thead>
<tr>
<th>Food item</th>
<th>calculated kcal ME/g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular Dog Chunks, Dry</td>
<td>4.06</td>
</tr>
<tr>
<td>Weight Control for Dogs, Dry Omnivore,</td>
<td>3.85</td>
</tr>
<tr>
<td>Dry</td>
<td>2.80</td>
</tr>
<tr>
<td>Zoo Carnivore Diet 5% Fish</td>
<td>1.19</td>
</tr>
<tr>
<td>Analog</td>
<td>1.15</td>
</tr>
<tr>
<td>Rabbit, whole</td>
<td>1.35</td>
</tr>
<tr>
<td>Trout, whole</td>
<td>1.09</td>
</tr>
<tr>
<td>Herring, whole</td>
<td>1.78</td>
</tr>
<tr>
<td>Mackeral, whole</td>
<td>1.00</td>
</tr>
</tbody>
</table>

1 The IAMS Company, 7250 Poe Avenue, Dayton, Ohio 45414
2 Mazuri, St. Louis, MO
3 Natural Balance, 12924 Pierce Street, Pacoima, California 91331

Changes in body mass, independent of the quantity of metabolizable energy offered, are clearly indicated in Figures 1-4. Based on this experience, it is presumed that dramatic seasonal weight changes demonstrated in this species can be modulated through active management of diet.
Figure 1. Changes in body weight (BW, kg) and total metabolizable energy intake (Intake, kcal ME) during 2004 in a three-year old, male polar bear housed in southern California.

Figure 2. Changes in body weight (BW, kg) and total metabolizable energy intake (Intake, kcal ME) during 2004 in a three-year old, female polar bear housed in southern California.
Figure 3. Changes in body weight (BW, kg) and total metabolizable energy intake (Intake, kcal ME) during 2004 in a nine-year old, female polar bear housed in southern California.

Figure 4. Changes in body weight (BW, kg) and total metabolizable energy intake (Intake, kcal ME) during 2004 in a nine-year old, female polar bear housed in southern California.
b. Nutritionally complete products available:
The diet items polar bears consume in the wild are not available for feeding in captivity. Thus, it is the nutrients, and not their packaging, that should be considered. Various food items, such as nutritionally complete dry foods, raw nutritionally complete meat mix, gel nutritionally complete products, marine products, bones/prey, and produce, when fed in combination, should result in nutrient levels that meet the minimum dietary recommendations (section 3.1, Table 1). Nutrients in items that are commercially available may vary depending on the location and time of the year. Fish is often a large part of many polar bear diets. The nutrient content of fish can vary greatly (Bernard et al., 1997). Consequently, regular analysis of diet ingredients and diet review are imperative to offering appropriate captive diets.

Several manufacturing technologies exist which may be applicable to polar bear diets. All of the technologies described below are either in use or have the potential to be used with captive polar bears. Each type of product has its advantages and disadvantages. Any of these technologies may be used alone, or in combination, to provide complete diets for polar bears. Feed manufacturing information provided by Mark Griffin, personal communication (2004).

**Extrusion.** Extrusion is a diet manufacturing technology that uses steam, compression and friction to quickly pressure cook the diet. Typically, dry ingredients are mixed, ground and then steam-conditioned before reaching the extruder. In the extruder, more steam and water is added. The ingredients typically become an amorphous mass (i.e. dough). The extruder quickly pressure cooks the diet. The diet may be cut into various sizes and shapes. The cut diet is then dried, typically to less than 11% moisture content. The low moisture content allows for an extended shelf life.

The vast majority of commercial dog, cat and fish foods are prepared by extrusion. Extruded diets have numerous benefits when compared to other diets.
- Stable shelf life compared to wet diets
- Increased palatability versus pelleted diets
- Cooked starch increases starch digestibility in dogs and cats versus pelleted diets
- Fewer fines than pellets
- Nutritionally complete particles, compared to mixed food items
- Better dental health compared to ground meat products
- Low microbial load

**Pelleted Diets.** Pelleted diets are manufactured from ground ingredients that are compressed into cylinder-shaped particles. These diets differ from extruded products in that they are comprised of recognizable ingredient particles. They are more dense and do not have the same degree of “cook.” Pelleted diets tend to have more fines, which are the powder or very small particles from crumbled diet. Pelleted diets are not typically dried, so they tend to have slightly more moisture than extruded diets, which is why mold inhibitors are frequently used in pellets. Starch tends to be less digestible and pellets tend to be less palatable than extruded particles to carnivores and omnivores. Pelleting uses much less energy than extrusion; therefore, manufacturing costs are substantially less.
**Raw Meat Complete Diets.** Ground meat diets use a variety of raw animal components (i.e. muscle, organs, fat), and then are supplemented with various “minor” ingredients (i.e. vitamins and minerals). Muscle-based products result in the most uniform products. Some diets do contain appreciable quantities of organs, which tend to increase nutrient variability. Ground meat diets are highly perishable, unless preserved. Most of these diets are stored frozen. These diets have the potential to have excellent nutrition and typically are highly palatable. Proper handling, at the time of manufacture, during storage and thawing, and prior to feeding the thawed product, is critical to minimize the potential microbial contamination.

**Gel Complete Diets.** Gel diets are high moisture products formed with either a protein or carbohydrate gel matrix that contains a fixed set of nutrients. The advantages of these diets are the nutritional flexibility and palatability. Gels have the same disadvantages of other wet diets; they are highly perishable. Gel diets have been used with bears and may be particularly useful for medication or treats.

c. Food categories and suggested ranges with flexibility for seasonal changes

Tables 4 outlines food item categories and suggested ranges for these food categories in the diet. Following the outline categories and ranges will allow the diet offered to meet the minimum dietary recommendations for polar bears outlined in Table1.

**Table 4. Food categories and suggested ranges with flexibility for seasonal changes**

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>As Fed % of the Diet</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance/Growth/Lactation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry Nutritionally Complete Food</td>
<td>5</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Raw Meat Mix Nutritionally Complete</td>
<td>30</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>Marine Products – saltwater fish</td>
<td>15</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Produce</td>
<td>0</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Meat from Shank Bone^4</td>
<td>5</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Whole Prey^5</td>
<td>0</td>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td>Misc.</td>
<td>0</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

^1 see appendix for nutrient analysis of diets. See appendix 9 section b. **Diets outside these ranges could be fed if nutrient content of ingredients when consumed as offered meet target nutrient ranges.**

^2 See section b above for explanation; See appendix 9 section c for specifications for appropriate nutritionally complete foods.

^3 See section b above for explanation, See appendix 9 section d for specification for appropriate nutritionally complete meat mix.

^4 Meat from a shank bone is 50% of the total bone weight (i.e. if a bones weighs 454 grams then 227 grams is meat).

^5 Whole prey is large rats or rabbit.

^6 Miscellaneous may include items for behavioral enrichment (BE), see appendix 9, section e.
d. Sample diets:
Table 5 outlines 2 successful sample diets from zoological institutions in the U.S that have reproductive success or bears in good body condition. Table 6 provides the nutrient analysis of those 2 diets.

Table 5. Food categories and quantities of sample diet as fed

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Brookfield Zoo, %</th>
<th>San Diego Zoo, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nutritionally complete dry diet</td>
<td>18.1</td>
<td>14.8</td>
</tr>
<tr>
<td>Nutritionally complete raw diet</td>
<td>26.8</td>
<td>36.2</td>
</tr>
<tr>
<td>Nutritionally complete gel diet</td>
<td>-</td>
<td>6.9</td>
</tr>
<tr>
<td>Saltwater Fish</td>
<td>23.6</td>
<td>15</td>
</tr>
<tr>
<td>Meat from Shank Bone</td>
<td>3.8</td>
<td>2.8</td>
</tr>
<tr>
<td>Whole Prey</td>
<td>-</td>
<td>8.0</td>
</tr>
<tr>
<td>Produce</td>
<td>27.7</td>
<td>16.3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

Table 6. Nutrient analysis of sample diets on a dry matter basis

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Unit</th>
<th>Minimum Dietary Recommendations Polar Bear&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Brookfield Zoo&lt;sup&gt;b&lt;/sup&gt;</th>
<th>San Diego Zoo&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td>%</td>
<td>25</td>
<td>35.3</td>
<td>43.8</td>
</tr>
<tr>
<td>Fat</td>
<td>%</td>
<td>5-20</td>
<td>14.0</td>
<td>16.9</td>
</tr>
<tr>
<td>Taurine</td>
<td>%</td>
<td>0.1</td>
<td>0.1</td>
<td>-</td>
</tr>
<tr>
<td>Linoleic acid</td>
<td>%</td>
<td>1</td>
<td>1.28</td>
<td>1.16</td>
</tr>
<tr>
<td>Vitamin A</td>
<td>IU/g</td>
<td>5</td>
<td>8.91</td>
<td>15.65</td>
</tr>
<tr>
<td>Vitamin D&lt;sub&gt;3&lt;/sub&gt;</td>
<td>IU/g</td>
<td>1.8</td>
<td>2.18</td>
<td>2.12</td>
</tr>
<tr>
<td>Vitamin E</td>
<td>IU/kg</td>
<td>100</td>
<td>165</td>
<td>289.4</td>
</tr>
<tr>
<td>Thiamin</td>
<td>mg/kg</td>
<td>5</td>
<td>5.33</td>
<td>10.1</td>
</tr>
<tr>
<td>Riboflavin</td>
<td>mg/kg</td>
<td>4</td>
<td>5.57</td>
<td>11.1</td>
</tr>
<tr>
<td>Niacin</td>
<td>mg/kg</td>
<td>40</td>
<td>52.45</td>
<td>53</td>
</tr>
<tr>
<td>Pyridoxine</td>
<td>mg/kg</td>
<td>4</td>
<td>5.23</td>
<td>5.4</td>
</tr>
<tr>
<td>Folacin</td>
<td>mg/kg</td>
<td>0.5</td>
<td>0.79</td>
<td>1.2</td>
</tr>
<tr>
<td>Biotin</td>
<td>mg/kg</td>
<td>0.07</td>
<td>0.07</td>
<td>--</td>
</tr>
<tr>
<td>Vitamin B&lt;sub&gt;12&lt;/sub&gt;</td>
<td>mg/kg</td>
<td>0.02</td>
<td>0.02</td>
<td>--</td>
</tr>
<tr>
<td>Pantothenic acid</td>
<td>mg/kg</td>
<td>5</td>
<td>4.11</td>
<td>23</td>
</tr>
<tr>
<td>Choline</td>
<td>mg/kg</td>
<td>1200</td>
<td>1149</td>
<td>1920</td>
</tr>
<tr>
<td>Calcium</td>
<td>%</td>
<td>0.6</td>
<td>2.03</td>
<td>1.43</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>%</td>
<td>0.5</td>
<td>1.44</td>
<td>1.24</td>
</tr>
<tr>
<td>Magnesium</td>
<td>%</td>
<td>0.04</td>
<td>0.1</td>
<td>0.108</td>
</tr>
<tr>
<td>Potassium</td>
<td>%</td>
<td>0.6</td>
<td>1.16</td>
<td>0.899</td>
</tr>
<tr>
<td>Sodium</td>
<td>%</td>
<td>0.2</td>
<td>0.62</td>
<td>0.432</td>
</tr>
<tr>
<td>Iron</td>
<td>mg/kg</td>
<td>80</td>
<td>136</td>
<td>199.8</td>
</tr>
<tr>
<td>Zinc</td>
<td>mg/kg</td>
<td>97</td>
<td>119.2</td>
<td>111.1</td>
</tr>
<tr>
<td>Nutrient</td>
<td>mg/kg</td>
<td>Upper Limit</td>
<td>Lower Limit</td>
<td></td>
</tr>
<tr>
<td>---------</td>
<td>-------</td>
<td>-------------</td>
<td>-------------</td>
<td></td>
</tr>
<tr>
<td>Copper</td>
<td>10</td>
<td>13.3</td>
<td>25.5</td>
<td></td>
</tr>
<tr>
<td>Manganese</td>
<td>7.5</td>
<td>11.56</td>
<td>38.0</td>
<td></td>
</tr>
<tr>
<td>Iodine</td>
<td>1.5</td>
<td>--</td>
<td>2.55</td>
<td></td>
</tr>
<tr>
<td>Selenium</td>
<td>0.1</td>
<td>0.15</td>
<td>0.39</td>
<td></td>
</tr>
</tbody>
</table>

*Suggested minimum polar values complied by the polar bear nutrition working group. Nutrient levels of successful zoo diets are those consumed by animals in good body condition with successful reproduction.*

e. Presentation and sequence of feeding
After discussion among nutritionists and veterinarians, we recommend feeding food items that are soft or that could become soft first. For instance, the nutritionally complete hard foods could become soft and stick to the teeth. Food items such as bones, fish, or those with hair/skin should be offered last. This may improve oral health. Additionally, bears may need bones more than once a week for assistance in dental health. When considering food presentation for enrichment, variation of the food, different avenues to present food, placement of the food, and timing should be considered.

f. Carcass feeding
The feeding of road kill should be discouraged. If road kill are used they must be fresh, wholesome, in good condition (well flesheled, not bloated), free from obvious disease (no external lesions or wasted appearance), and fed as soon as possible. The carcass must be removed when spoilage begins, or 12 hours (USDA recommendation but may need to be modified according to environmental temperatures) after it has been placed into the enclosure, whichever comes first. Carcasses, whether fed out immediately or processed for freezing, should be opened (abdominally then up through the diaphragm) and organs inspected for internal lesions or abnormalities which might indicate presence of infectious disease (i.e. abscesses, parasites, etc). This inspection is best performed by a veterinarian/pathologist.

Sick animals, or animals that have died of illness or unknown causes, must not be used for food. Animals euthanized with chemical euthanizing agents must not be used for food because of danger of poisoning. When food animals have been euthanized by gunshot, the lead should be removed to prevent lead poisoning from ingestion of the pellets. Downer animals exhibiting signs of central nervous system disorders, including dairy and beef cows, horses, other livestock (particularly sheep), and wildlife, must not be used for food because of the risk of transmissible spongiform encephalopathies. This includes animals suffering from scrapie and any chronic wasting disease. If the downer animals were clearly harvested because of physical injuries only, they may be used for food when properly processed. In addition, animals known or suspected of being affected with Johne’s disease should not be fed.

g. Browse/Deleterious plant list
Plant materials introduced into, or growing in animal enclosures should be evaluated as if the exposed animals will ingest them. Plants should be screened for a number of criteria, including, but not limited to: known toxicities to comparable species (i.e. dogs, cats,
humans); potential to cause obstruction of the gastrointestinal tract, physical irritation and exposure to pesticides, herbicides, and other noxious chemicals.

A partial list of resources to determine plants that may be deleterious to various animal species is summarized in Appendix 9 section p.

h. Sanitation/food handling
Care should be taken to ensure that the food for captive animals is of the highest quality. The Code of Federal Regulations states that “food shall be wholesome, palatable, and free from contamination, and shall be of sufficient quality and nutritive value to maintain all animals in good health” (9 CFR 3.129).

Meat

Identifying the product
History of the freshness and wholesomeness of the meat, the source of the prey item and the history of processing should be ascertained. Any supplier utilized for meat products should have an effective quality assurance program. This program should include agreed specifications, auditing of suppliers and Certificate of Analysis. Additionally, raw material or finished products’ specifications should include details of manufacturer, a description of the raw materials, ingredients breakdown, absence of hazardous organisms, analytical/microbial sampling plan, labeling, storage/distribution conditions, safe handling/use instructions, and description of pack type/size/quantity.

Inspection of the product
Ideally, an inspection-site visit to the manufacturer to see handling and processing would ensure the best possible product. Since a visit to the manufacturer is not always possible the products should be inspected upon arrival to the institutions. The products should be delivered during business hours, inspected quickly and stored immediately in the freezer. At minimum, open and examine at least 10% or a minimum of three packages in the front, middle, and end of the load. Look for evidence that the product may have been frozen, thawed and refrozen. Evidence could include water or ice buildup on the boxes or floor, wrappings that are moist, slimy, or discolored. Inspection upon arrival also should include the truck in which the product is delivered. The truck should not include nonfood items and the temperature in the truck should indicate frozen conditions. See appendix 9, section f for the check sheet. See appendix 9, section g for quality control standards for meat and whole prey.

Storage of the product
Once the product is stored in the freezer it is important to make sure the old product is used first. Optimally, the date received should be placed on the product upon arrival. Optimal freezer temperatures range from -30 to -18°C (-22 to 0°F). Refrigeration should be used only
for thawing. Incorrect thawing may result in nutritive losses, lipid peroxidation (rancidity), microbial buildup, and loss of palatability. Products should not be thawed at room temperature.

Some institutions use meat that has not been frozen. These products should be handled similarly to thawed products. Thawed products should be kept iced or refrigerated until the time of feeding. While handling thawed product before feeding, it should be inspected for quality. This should be performed quickly to minimize contamination and microbial buildup. Utensils and surfaces used while preparing the product should be cleaned and sanitized following established and approved protocols.

Processes and procedures used with meat products should be validated and reviewed periodically. Sampling of the meat products should be done once a year at the minimum for nutritional analysis and microbial loads. It would be ideal to have every shipment tested.

Fish

Local sanitation regulations may vary from state to state. Therefore, care should be taken to review any relevant state or local regulations with respect to instituting or modifying the guidelines presented in this document. As more information on fish contamination, diseases, and sanitation becomes available, it should be used to update and augment these guidelines.

Identifying the product
Most captive polar bears are fed frozen, thawed fish. Since daily food availability is crucial to any captive program, most fish purchases are made in bulk. This requires the items to be frozen and stored until use. Given the perishable nature of fish, appropriate food-handling procedures are crucial to the nutritive quality of the food and consequently to the successful management and welfare of the animals.

The term “fish” is used throughout this document to mean all fish, including freshwater and saltwater fish, and other seafood items (squid, clams, etc.) that may be fed to fish-eating animals. Types of fish selected for use by an institution are chosen for specific nutrient content, quality, availability, price, and animal preference. The nutrient value of fish varies considerably due to several factors: species differences, individual differences due to season of capture, age, and sex (Stoskopf, 1986).

Nutrition and quality must be considered major factors in fish selection. Care must be taken to ensure that food for captive marine animals is of the highest quality. USDA regulations state that “food for marine mammals shall be wholesome, palatable, and free from contamination, and shall be of sufficient quality and nutritive value to maintain all of the marine mammals in a state of good health” (9 CFR 3.105). Consumption of fish that are contaminated with high levels of bacteria is a serious health problem for animals as well as for handlers processing the food.
In order to avoid ultimate dependence on one particular food item, it is prudent to offer a variety of fish to the animal. It is possible for an animal to become imprinted on a specific food item. If that item becomes unobtainable, it may be very difficult to coax the animal to eat a new species. In addition, offering a variety of food items helps to ensure a complementary nutrient profile in the diet. Geraci (1978) emphasizes the need to feed more than one food type, including high- and low-fat fishes, in order to help ensure a balanced diet.

Fish Supply

Uncertainties in the future availability of fish stocks, reliance on farmed fish, and the development of technologies such as a fish substitute for marine mammal diets: These factors make selection of appropriate fish and their handling of utmost importance. Such uncertainties and possibilities require an awareness and evaluation of the nutritional content and quality of diets.

To determine the freshness and wholesomeness of fish, the history of the catch should be ascertained. This history should include knowledge of pre-capture conditions. Epidemiological data such as local and periodic occurrences of pesticide and heavy metal pollution also are useful (Stoskopf, 1986). The broker or fishery can be contacted for this information. Also, for information about current fish supplies, status, or contamination problems, newspapers and fisheries reports may be helpful. Additionally, request that a catch date be recorded on the boxes received to provide an indication of freshness of fish. The date can provide a link between the catch and environmental events that may have affected it.

As conservation minded institutions, zoos and related facility should, to the best of their ability, base the selection of fish species used in animal diets on the status and sustainability of the species’ wild populations.

Inspection of the product

In order to meet USDA standards, all fish should be of the same quality as that intended for human use (9 CFR 3.105). Therefore, fish fed to animals should be supplied from fisheries that have caught, processed, and stored the fish as if they were intended for human use. The primary difference between fish for human use and those for captive fish-eating animals is that whole fish are usually fed to animals. Therefore, it is not required that the product be deboned and cleaned of internal organs.

The packaging of fish by a processor can play a significant role in fish quality. Fish must be packaged in plastic-lined boxes with date of catch printed on the box. Fish may be block frozen, individually quick frozen (IQF), or in a shatter pack. The optimal size for packages should be 10-20 kg to allow for proper thawing. It is suggested that package size provide 1 day's supply without leftovers (Stoskopf, 1986). Package size is also determined by the type and usage of fish. Those fish used in smaller quantities should be purchased in smaller packages or should be prepared in a manner that allows for easy access to smaller quantities (by using IQF or shatter pack).
Ideally, to ensure that fresh fish are handled appropriately throughout processing by the fisheries, the fisheries should be visited during processing and the fish inspected at that time. Since this may be impractical for most institutions, they should concentrate on a thorough inspection when the product arrives at the storage facility.

The first step in quality control is at the delivery stage. Since products should be inspected and processed immediately, schedule deliveries during business hours. An inspection should occur at the place of receipt (storage site) before or possibly during unloading of the shipment so that a representative number of boxes can be examined. Inspection must be performed by one of the zoo's or aquarium's employees who are familiar with proper inspection techniques and fish quality. A thorough inspection should include looking for signs of pests around and inside containers, maintenance of proper temperatures during shipment, and signs of thawing and refreezing (Crissey et al. 1987).

Every lot or shipment of fish must be inspected before paperwork is signed to officially receive it from the supplier.

When thawed, fresh fish have bright red gills, prominent clear eyes, have firm, and elastic flesh (see appendix 9, section h for fish quality standards). Old or thawed and refrozen fish are dull in appearance, have cloudy and red-bordered eyes, and have soft flesh, and finger impressions are made easily and remain (U.S. Navy 1965). If the quality is questionable, it is wise to thaw a few fish from several packages for a better determination. Again, try to do this before officially accepting the shipment. If the order is acceptable, a sample of fish should be taken for nutrient analyses at this time. If the fish have been found to be unsatisfactory for any reason, refuse to take receipt, even if that means reloading the vehicle. The shipper should take the load back. If there is any disagreement as to the quality of the product or what the shipper is to do with it, contact the supplier. Bad fish are unusable, unpalatable, and a health hazard and may cause a significant economic loss due to illness or death of the animals.

Storage of the product
Once a fish shipment has been accepted, it should be placed immediately in the institution's storage facility. This facility should be designed to adequately protect supplies from deterioration or contamination. It is crucial that the length (not more than 1 year) and conditions of storage minimize contamination and ensure that the product retains its nutritive value and wholesome quality.

Prior to storing a new shipment, inspect the storage freezer to ensure that it is in good working order. There should be no potential for contamination by chemicals or other items that may also be stored in the freezer. Any older stock remaining in the freezer should be placed so that it will be used before the new stocks on a “first in, first out” basis. Always rotate shipments of the same species of fish to help ensure freshness. Optimally, the date received should be stamped or written on a box or pallet of boxes (Crissey et al. 1987).
Once the product is stored in the freezer it is important to make sure the old product is used first. Optimally, the date received should be placed on the product upon arrival. Optimal freezer temperatures range from -30 to -18°C (-22 to 0°F). Refrigeration should be used only for thawing. Incorrect thawing may result in nutritive losses, lipid peroxidation (rancidity), microbial buildup, and loss of palatability. Products should not be thawed at room temperature. If it is necessary to transport fish from bulk freezer storage to a location used for storing smaller quantities and subsequent thawing and processing (kitchen preparation area), then such transportation must be accomplished in a manner that keeps the fish solidly frozen. The vehicle should be cooled or insulated. If this is not possible, procedures must be taken to cover or insulate the load while in transit, depending on outside environmental conditions. The length of transportation time necessary to move stock from storage to the appropriate short-term storage or preparation area should be minimized. It is recommended that the temperature of fish in transit be monitored by placing a thermometer in one or more of the boxes during transport. This could be a maximum/minimum thermometer or another temperature-sensing or -recording device. If temperature is monitored, it should be documented. Any boxes thawed or partially thawed during transportation should be used immediately and not refrozen.

Fish should be handled similarly to thawed products. Thawed products should be kept iced or refrigerated until the time of feeding. While handling thawed product before feeding, it should be inspected for quality. This should be performed quickly to minimize contamination and microbial buildup. Utensils and surfaces used while preparing the product should be cleaned and sanitized following established and approved protocols.

Processes and procedures used with fish should be validated and reviewed periodically. Sampling of the fish should be done once a year at the minimum for nutrient analysis and microbial loads.

5. ASSESSING BODY CONDITION

In Table 7 below are various ways that condition of bears can be visually judged or measured.

**a. Table 7. Standard body scoring of polar bears used by field biologist**

*Provided by Polar Bear Specialist Group (S.Amstrup)*

<table>
<thead>
<tr>
<th>1</th>
<th>Pelvis and scapulae protruding, ribs easily palpated. A deep hollow will be noted between the pelvis and last rib showing virtually no fat.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Pelvis easily palpated, ribs also felt on palpation, but having some muscle covering them. The hollow between the pelvis and last rib obvious, but softer.</td>
</tr>
<tr>
<td>3</td>
<td>Body is fully fleshed out. Obvious fat is present over pelvis and shoulders, ribs less obvious. The hollow between the pelvis and last rib absent.</td>
</tr>
<tr>
<td>4</td>
<td>Bear has a rounded or blocky appearance, very well fleshed over all bony areas, obvious fat over rump and shoulders.</td>
</tr>
<tr>
<td>5</td>
<td>Legs appear too short for the body, rolls of fat on neck and lower shoulders.</td>
</tr>
</tbody>
</table>

b. BIA – Bioelectrical Impedance Analysis indirectly measures body fat content by passing a low voltage current through the body. Resistance to the flow of electricity within the body is
directly proportional to body fat content. This technique has been calibrated for polar bears (Farley and Robbins 1994). Below is a description of the method. However, those wishing to use this method should contact the authors to receive training.

Determination of Body Composition of Polar Bears by Bioelectrical Impedance Analysis


1) Body Mass Determination
   a) Whether the bear is weighed in the lab or field, always make sure that the scale is zeroed and functioning correctly.
   b) Under field conditions, correct for the mass of the weighing apparatus (e.g., tarp) and make sure that nothing is interfacing with the weigh measurement.
   c) Record body mass (BM) in kilograms

2) Snout-Vent Length Measurement
   a) Position the animal in a sternally recumbent position with great care to standardize the position for all animals. Check the animal very carefully for any wounds or infections that would produce erroneous BIA readings (Figure X).
   b) Measure the distance from the tip of the snout to the base of the tail at the vent. Follow the natural contours of the animal’s body.
   c) Record snout-vent length (SVL) in centimeters.

3) Resistance Measurement
   a) The following instruments have been recommended for this application
      i) Bioelectrical Impedance Analyzer, Model 101A, RJL Systems
         (www.rjlsystems.com)
         (1) Note, this unit is no longer produced by the manufacturer
      ii) Bioelectrical Impedance Analyzer, Quantum II, RJL Systems
          (www.rjlsystems.com)
   b) With the animal in the same position as Section 2, connect the electrodes to the bear. The anterior pair of electrodes is clamped to the lips at the level of the upper canine tooth (Figure X). The posterior pair is connected to 21 gauge, 3.8 cm Vacutainer® needles. The short side of each needle is inserted 3 cm to either side of the tail (Figure X). For both pairs of electrodes, the current carrying electrode (red) is placed
on the animals’ right side. The black electrode pair is connected to the animal’s left side.

c) Once the anterior pair of electrodes is clamped to the lips, gently massage the lips at the site of electrode attachment while watching the instrument display to ensure good contact is occurring and that resistance is not changing.

d) If either the animal or the ground is wet, the animal should be placed on a plastic tarp to prevent conductance between the animal and the ground.

e) Record the resistance measurement in ohms.

4) Body Composition Determination

a) Total body water content (TBW, kg) can be calculated from the following equations (Farley and Robbins, 1994).

b) \[ TBW = -1.860 + 0.231 \left( \frac{SVL^2}{STAILR} \right) + 0.074 (BM) \]

c) Where TBW is total body water (kg), SVL is snout-vent length (cm), STAILR is resistance (ohms), and BM is body mass (kg).

6. SERUM NUTRIENT NORMS

Table 8. Serum concentrations of vitamin D metabolites and vitamins A and E.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Captive</td>
<td>Captive</td>
<td>Free-ranging</td>
</tr>
<tr>
<td>N Value ±SD</td>
<td>Value ±SD</td>
<td>Value ±SD</td>
<td>Value ±SD</td>
</tr>
<tr>
<td>25(OH)D, ng/ml</td>
<td>5 64±11</td>
<td>36 139±86</td>
<td>56 144±54</td>
</tr>
<tr>
<td>1,25(OH)2D, pg/ml</td>
<td>5 18±4.2</td>
<td>- ua</td>
<td>- ua</td>
</tr>
<tr>
<td>Retinol, µg/dl</td>
<td>4 25±1.8</td>
<td>- ua</td>
<td>- ua</td>
</tr>
<tr>
<td>Retinyl palmitate, µg/dl</td>
<td>4 4.9±1.3</td>
<td>- ua</td>
<td>- ua</td>
</tr>
<tr>
<td>Retinyl stearate, µg/dl</td>
<td>4 2.9±0.8</td>
<td>- ua</td>
<td>- ua</td>
</tr>
<tr>
<td>α-tocopherol, µg/dl</td>
<td>4 3362±193</td>
<td>32 800±800</td>
<td>56 2101±600</td>
</tr>
<tr>
<td>γ-tocopherol, µg/dl</td>
<td>4 40±5.8</td>
<td>- ua</td>
<td>- ua</td>
</tr>
</tbody>
</table>

ua=unavailable

25(OH)D is the most valid measure for assessing vitamin D stores because it reflects vitamin D intake and photobiogenesis over several weeks to months. 1,25(OH)2D is more reflective of immediate ingestion or exposure and not stores. Retinol has been used as criteria of vitamin A status. However, serum levels of vitamin A tend to be homostatically controlled at a level that is largely independent of total body reserves (Crissey et al, 1999). Alphatocopherol is the most abundant tocopherol in animal tissues. There is a high correlation among plasma, dietary intake and liver levels of α-tocopherol. However, there are major differences among species in normal circulating α-tocopherol levels, and different animals of the same species tend to exhibit individually characteristic plasma α-tocopherol levels.
concentrations (Shrestha, et al, 1998). Thus values of low sample size may not be reflective of vitamin E status.

The recommended dietary levels of fat soluble vitamins required to produce healthy captive polar bears have long been of concern (Foster 1981). Wild polar bears are known to store large amounts of these vitamins in their liver and fat and have high serum concentrations as biomagnification occurs with increasing trophic level in the marine food chain (Crissey et al. 1999, Kenny 2004). For example, 25(OH)D in wild and captive polar bears (Table 8) are several times higher than human standards (15-30 ng/ml) (Holick 1999) and vitamin A levels in wild polar livers are toxic when consumed by humans (Robbins 1993). The very high serum levels of fat soluble vitamins in wild polar bears have led many to hypothesize that captive polar bear diets should be heavily supplemented with vitamins A, D and E. However, thus far there has been no consistent improvement in the health of captive polar bears when supplemented with large doses of these vitamins. Thus, while serum levels for all of these vitamins are of interest and need to be monitored, excess supplementation should be discouraged until convincing evidence shows that these levels are indeed necessary and not simply part of a homeostatic mechanism for dealing with high dietary intake.

The results of several studies on serum concentrations of total cholesterol triacylglyceride, HDL cholesterol, and LDL cholesterol are summarized in Table 9 (Crissey, et al., 2004, Brannon, 1985, Schweigert, 1990).

Table 9. Serum concentrations of total cholesterol, triacylglyceride, HDL cholesterol, and LDL cholesterol.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Value ±SEM</td>
<td>N</td>
</tr>
<tr>
<td>Total cholesterol, mmol/L</td>
<td>6</td>
<td>8.9±0.76</td>
<td>29-35</td>
</tr>
<tr>
<td>Triacylglyceride, mmol/L</td>
<td>6</td>
<td>2.91±0.48</td>
<td>29-35</td>
</tr>
<tr>
<td>HDL cholesterol, mmol/L</td>
<td>6</td>
<td>5.8±0.37</td>
<td>-</td>
</tr>
<tr>
<td>LDL cholesterol, mmol/L</td>
<td>5</td>
<td>6.8±1.49</td>
<td>-</td>
</tr>
</tbody>
</table>

ua=unavailable
7. ASSESSING STOOL CONDITION
Figure 5 can be used as a tool to communicate objectively any changes in an individual’s stool quality.

<table>
<thead>
<tr>
<th>SCORE 0</th>
<th>Very loose, no form, possibly blood</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCORE 25</td>
<td>Mixture of formed and unformed, mostly loose</td>
</tr>
<tr>
<td>SCORE 50</td>
<td>Formed feces, but very soft</td>
</tr>
</tbody>
</table>
8. HAND REARING

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Age (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eyes open</td>
<td>24-42</td>
</tr>
<tr>
<td>Incisors erupt 36-53</td>
<td>46-53</td>
</tr>
<tr>
<td>Canines erupt 46-53</td>
<td>60-82</td>
</tr>
<tr>
<td>Stand</td>
<td></td>
</tr>
</tbody>
</table>

a. Background
Polar bear cubs weigh 600-700 grams at birth. Twins are most common, but as many as four cubs can be born (Briggs, 2001). Mother bears can care for their cubs for up to 28 months, however this depends on weather conditions and age of the female in the wild (Briggs, 2001). In captivity, medical problems have been noted in some cubs associated with formula composition including rickets/vitamin D deficiency (Kenny, 1999), thiamin deficiency (Hess, 1976), lactobezors, constipation, dehydration, and bloating (Hess, 1976; Kenny, 1999). Developmental milestones in captive polar bear cubs are listed below.

Developmental milestones in captive polar bears

b. Milk composition
In general, bear milk tends to be higher in total solids, fat and protein, but lower in carbohydrates compared to other carnivores (Gittleman and Oftedal, 1987) and more closely resembles that of marine mammals (Jenness et al., 1972). Milk composition changes over the course of lactation. The fat content of wild polar bear milk is highest (35.8%) when emerging.
from the den in spring, gradually decreasing to 20.6% one year later while still on land. Lactating bears on sea ice showed no changes in the fat content of the milk as the age of the cubs increased (Derocher et al., 1993). Table 1 provides data on milk samples from polar bears.

Table 10. Composition of polar bear milk (as fed basis) (‘nd’ = not determined); numbers in parenthesis represent number of samples.

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Jenness (7)</th>
<th>Ben Shaul (1)</th>
<th>Derocher (128)</th>
<th>Kenny Captive (1)</th>
<th>Kenny Captive (1)</th>
<th>Kenny Freeranging (10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage of Lactation</td>
<td>1</td>
<td>unk</td>
<td>2</td>
<td>80 days</td>
<td>191 days</td>
<td>3-4 mos est.</td>
</tr>
<tr>
<td>Total Solids, %</td>
<td>47.6</td>
<td>24</td>
<td>41.6</td>
<td>34.7</td>
<td>45.9</td>
<td>52.5</td>
</tr>
<tr>
<td>Fat, %</td>
<td>33.1</td>
<td>9.5</td>
<td>28.5</td>
<td>23.4</td>
<td>30.1</td>
<td>35.8</td>
</tr>
<tr>
<td>Carbohydrate, %</td>
<td>0.3</td>
<td>3.0</td>
<td>2.5</td>
<td>1.7</td>
<td>0.6</td>
<td>4.7</td>
</tr>
<tr>
<td>Casein, %</td>
<td>7.1</td>
<td>nd</td>
<td>nd</td>
<td>nd</td>
<td>nd</td>
<td>nd</td>
</tr>
<tr>
<td>Whey Protein, %</td>
<td>3.8</td>
<td>nd</td>
<td>nd</td>
<td>nd</td>
<td>nd</td>
<td>nd</td>
</tr>
<tr>
<td>Total Protein, %</td>
<td>10.9</td>
<td>9.6</td>
<td>11.4</td>
<td>8.5</td>
<td>13.7</td>
<td>10.5</td>
</tr>
<tr>
<td>Ash, %</td>
<td>1.4</td>
<td>1.2</td>
<td>nd</td>
<td>1.1</td>
<td>1.5</td>
<td>nd</td>
</tr>
<tr>
<td>Calcium, %</td>
<td>0.29</td>
<td>nd</td>
<td>nd</td>
<td>0.23</td>
<td>0.37</td>
<td>nd</td>
</tr>
<tr>
<td>Phosphorus, %</td>
<td>0.23</td>
<td>nd</td>
<td>nd</td>
<td>0.18</td>
<td>0.25</td>
<td>nd</td>
</tr>
<tr>
<td>Vitamin D, ng/g</td>
<td>nd</td>
<td>nd</td>
<td>nd</td>
<td>28.7</td>
<td>nd</td>
<td>1.6±2.8</td>
</tr>
</tbody>
</table>

1 Stage of lactation: 4 cubs 7-8 months old, 1 10 mos old, 1 18-19 mos old, 1 unk
2 Stage of lactation: see table 2.

Table 11. Composition of polar bear milk (Derocher et al. 1993)

<table>
<thead>
<tr>
<th>Cub Age (months)</th>
<th>Fat (%)</th>
<th>Protein (%)</th>
<th>Carbohydrate (%)</th>
<th>Gross Energy (kJ/g)</th>
<th>Gravimetric total solids</th>
<th>Calculated total solids</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 (n=31)</td>
<td>35.8</td>
<td>10.5</td>
<td>4.7</td>
<td>16.9</td>
<td>32.3</td>
<td>52.4</td>
</tr>
<tr>
<td>4* (n=8)</td>
<td>33.9</td>
<td>9.1</td>
<td>3.6</td>
<td>15.2</td>
<td>40.1</td>
<td>47.0</td>
</tr>
<tr>
<td>10 (n=51)</td>
<td>27.5</td>
<td>12.1</td>
<td>1.8</td>
<td>14.0</td>
<td>40.2</td>
<td>43.8</td>
</tr>
<tr>
<td>16* (n=7)</td>
<td>32.0</td>
<td>10.9</td>
<td>1.5</td>
<td>16.1</td>
<td>45.3</td>
<td>49.4</td>
</tr>
<tr>
<td>22 (n=15)</td>
<td>20.6</td>
<td>13.2</td>
<td>2.1</td>
<td>11.7</td>
<td>34.5</td>
<td>38.3</td>
</tr>
<tr>
<td>28* (n=1)</td>
<td>33.2</td>
<td>11.3</td>
<td>1.3</td>
<td>15.5</td>
<td>48.7</td>
<td>47.3</td>
</tr>
<tr>
<td>34 (n=1)</td>
<td>16.8</td>
<td>12.5</td>
<td>2.3</td>
<td>9.7</td>
<td>29.5</td>
<td>33.0</td>
</tr>
<tr>
<td>Average</td>
<td>28.54</td>
<td>11.37</td>
<td>2.47</td>
<td>14.16</td>
<td>38.66</td>
<td>44.46</td>
</tr>
</tbody>
</table>

* Bears on sea ice (all other values are for bears on land)

c. Formula selection
If the cubs have not had the opportunity to nurse, then polar bear serum should be administered. It is recommended to supplement at 3-5 mL per pound of body weight in two doses spaced 5-10 days apart (Hedberg, 2005). Most institutions that have hand-reared polar bear cubs have used either a combination of milk products (cream or half and half) with Esbilac, various dilutions of Esbilac or a combination of Esbilac and another milk replacer.
(such as Multi Milk or Enfamil). Pediatric vitamins were added by most institutions, but may not be necessary if a nutritionally complete milk replacer is used. Polar bear milk is low in lactose (Urashima et al, 2000), however most milk replacers are bovine based and contain significant amounts of lactose. The ability of polar bear cubs to digest lactose has not been determined. For this reason, formula predigested with a lactase enzyme preparation (Lacteeze) has been employed by some institutions. Cod liver oil was frequently added to formulas, however a number of cubs have been raised successfully without it. Ursids can form indigestible lumps of casein called lactobezoars which can have serious health implications. Reducing casein (a milk protein) and increasing whey in the formula can help prevent this problem.

Following are formulas that have been used successfully at three institutions. Little data exist on healthy bears hand reared from day one. Consequently, formulas provided below are examples used with bears in different health status or age. Therefore, at this time it is not possible to recommend one formula to use. If a hand rearing situation arises it is recommended to contact these institutions for additional assessment. Table 3 lists the nutrient composition of these formulas.

San Francisco. Raised 1 bear from 1 day of age in 1982-1983
Day 1-5 1:3 Esbilac: water by volume

<table>
<thead>
<tr>
<th>Item</th>
<th>Amount/100g (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Esbilac powder</td>
<td>11.6</td>
</tr>
<tr>
<td>Boiled water</td>
<td>88.4</td>
</tr>
<tr>
<td>Liquid pediatric vitamins</td>
<td>0.5 ml</td>
</tr>
<tr>
<td>Karo Syrup</td>
<td>4 ml</td>
</tr>
</tbody>
</table>

Beginning day 4 added cod liver oil at 5 ml/day

Day 6-7 Esbilac 1:2.5 water by volume

<table>
<thead>
<tr>
<th>Item</th>
<th>Amount/100g (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Esbilac powder</td>
<td>14.0</td>
</tr>
<tr>
<td>Boiled water</td>
<td>86.0</td>
</tr>
<tr>
<td>Liquid pediatric vitamins</td>
<td>0.5 ml</td>
</tr>
<tr>
<td>Karo Syrup</td>
<td>4 ml</td>
</tr>
</tbody>
</table>
Added cod liver oil at 5 ml/day

Day 8-14 1:2 Esbilac: water by volume

<table>
<thead>
<tr>
<th>Item</th>
<th>Amount/100g (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Esbilac powder</td>
<td>16.4</td>
</tr>
<tr>
<td>Boiled water</td>
<td>83.6</td>
</tr>
<tr>
<td>Liquid pediatric vitamins</td>
<td>0.5 ml</td>
</tr>
<tr>
<td>Karo Syrup</td>
<td>4 ml</td>
</tr>
</tbody>
</table>

Added cod liver oil at 5 ml/day

Day 15-28 1:1.5 Esbilac: water by volume

<table>
<thead>
<tr>
<th>Item</th>
<th>Amount/100g (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Esbilac powder</td>
<td>20.8</td>
</tr>
<tr>
<td>Boiled water</td>
<td>80.3</td>
</tr>
<tr>
<td>Liquid pediatric vitamins</td>
<td>0.5 ml</td>
</tr>
<tr>
<td>Karo Syrup</td>
<td>4 ml</td>
</tr>
</tbody>
</table>

Added cod liver oil at 5 ml/day

Day 29+ 1:1 Esbilac: water by volume

<table>
<thead>
<tr>
<th>Item</th>
<th>Amount/100g (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Esbilac powder</td>
<td>28.2</td>
</tr>
<tr>
<td>Boiled water</td>
<td>71.8</td>
</tr>
<tr>
<td>Liquid pediatric vitamins</td>
<td>0.5 ml</td>
</tr>
<tr>
<td>Karo Syrup</td>
<td>4 ml</td>
</tr>
<tr>
<td>Neo-Calglucon</td>
<td>2.5 ml</td>
</tr>
</tbody>
</table>

Added cod liver oil at 7.5 ml/day (increased to 10 ml/day Day 58) Brookfield Zoo. Raised 1 bear from 5 days of age in 1999-2000

Brookfield Zoo’s cub had a host of medical issues in the first weeks of life including a high white count, thrush (possibly antibiotic induced) and dehydration. The formulas listed below are what were actually used for this cub and may not all be appropriate for a healthy cub. Final formula is presumed to be appropriate for a healthy cub, but has not been tested.

Formula 1 day 5-7

<table>
<thead>
<tr>
<th>Item</th>
<th>Amount/100g (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Esbilac powder</td>
<td>7.5</td>
</tr>
<tr>
<td>Multi-milk powder</td>
<td>7.5</td>
</tr>
<tr>
<td>Boiled water</td>
<td>85</td>
</tr>
<tr>
<td>Liquid pediatric vitamins (Poly-vi-sol)</td>
<td>1 drop</td>
</tr>
<tr>
<td>Liquid iron supplement (Fer-in-sol)</td>
<td>1 drop</td>
</tr>
<tr>
<td>Lactaid</td>
<td>3 drops</td>
</tr>
</tbody>
</table>

Formula 2 Day 8-17*
*Hydration issues and illness required dilutions or combinations with Formula 1 until Day 14.

San Diego Zoo. Raised 2 bears from approximately 90 days of age in 2001

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Amount g/100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Esbilac Powder</td>
<td>11.5</td>
</tr>
<tr>
<td>Enfamil Powder</td>
<td>11.5</td>
</tr>
<tr>
<td>Corn Oil</td>
<td>4</td>
</tr>
<tr>
<td>Water</td>
<td>73</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Amount g/100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Esbilac Powder</td>
<td>13.5</td>
</tr>
<tr>
<td>Enfamil Powder</td>
<td>13.5</td>
</tr>
<tr>
<td>Corn Oil</td>
<td>4</td>
</tr>
<tr>
<td>Water</td>
<td>69</td>
</tr>
</tbody>
</table>

Formula 3 Day 18-24

<table>
<thead>
<tr>
<th>Item</th>
<th>Amount/100g (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Esbilac powder</td>
<td>14.63</td>
</tr>
<tr>
<td>Multi-milk powder</td>
<td>7.32</td>
</tr>
<tr>
<td>Boiled water</td>
<td>75.61</td>
</tr>
<tr>
<td>Safflower oil</td>
<td>2.44</td>
</tr>
<tr>
<td>Liquid pediatric vitamins (Poly-vi-sol)</td>
<td>1 drop</td>
</tr>
<tr>
<td>Liquid iron supplement (Fer-in-sol)</td>
<td>1 drop</td>
</tr>
<tr>
<td>Lactaid</td>
<td>3 drops</td>
</tr>
</tbody>
</table>

Final formula used: Day 25 +

<table>
<thead>
<tr>
<th>Item</th>
<th>Amount/100g (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Esbilac powder</td>
<td>11.26</td>
</tr>
<tr>
<td>Multi-milk powder</td>
<td>5.63</td>
</tr>
<tr>
<td>Boiled water</td>
<td>81.23</td>
</tr>
<tr>
<td>Safflower oil</td>
<td>1.88</td>
</tr>
<tr>
<td>Liquid pediatric vitamins (Poly-vi-sol)</td>
<td>1 drop</td>
</tr>
<tr>
<td>Liquid iron supplement (Fer-in-sol)</td>
<td>1 drop</td>
</tr>
<tr>
<td>Lactaid</td>
<td>3 drops</td>
</tr>
</tbody>
</table>

San Diego Zoo. Raised 2 bears from approximately 90 days of age in 2001

Day 90-100

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Amount g/100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Esbilac Powder</td>
<td>11.5</td>
</tr>
<tr>
<td>Enfamil Powder</td>
<td>11.5</td>
</tr>
<tr>
<td>Corn Oil</td>
<td>4</td>
</tr>
<tr>
<td>Water</td>
<td>73</td>
</tr>
</tbody>
</table>

Day 101-222

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Amount g/100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Esbilac Powder</td>
<td>13.5</td>
</tr>
<tr>
<td>Enfamil Powder</td>
<td>13.5</td>
</tr>
<tr>
<td>Corn Oil</td>
<td>4</td>
</tr>
<tr>
<td>Water</td>
<td>69</td>
</tr>
</tbody>
</table>

Day 223-343

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Amount g/100</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

33 of 70
Table 12. Comparison of composition of hand-rearing formulas used to bottle-raise orphaned cubs (As fed basis). (c) indicates value was calculated using Atwater factors.

<table>
<thead>
<tr>
<th>Formula</th>
<th>Total solids, %</th>
<th>Fat, %</th>
<th>Carb, %</th>
<th>Protein, %</th>
<th>Ash, %</th>
<th>Ca, %</th>
<th>P, %</th>
<th>Na, %</th>
<th>K, %</th>
<th>Gross Energy, kcals/100g</th>
</tr>
</thead>
<tbody>
<tr>
<td>San Francisco</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>day 1-5</td>
<td>13.72</td>
<td>4.80</td>
<td>4.49</td>
<td>3.84</td>
<td>0.60</td>
<td>0.12</td>
<td>0.085</td>
<td>0.068</td>
<td>0.078</td>
<td>76.5 (c)</td>
</tr>
<tr>
<td>San Francisco</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>day 6-7</td>
<td>17.25</td>
<td>7.46</td>
<td>4.69</td>
<td>4.41</td>
<td>0.69</td>
<td>0.13</td>
<td>0.098</td>
<td>0.077</td>
<td>0.090</td>
<td>103.6 (c)</td>
</tr>
<tr>
<td>San Francisco</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>day 8-14</td>
<td>20.28</td>
<td>9.10</td>
<td>5.07</td>
<td>5.29</td>
<td>0.83</td>
<td>0.16</td>
<td>0.12</td>
<td>0.092</td>
<td>0.108</td>
<td>123.3 (c)</td>
</tr>
<tr>
<td>San Francisco</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>day 15-28</td>
<td>24.32</td>
<td>10.9</td>
<td>5.69</td>
<td>6.71</td>
<td>1.05</td>
<td>0.20</td>
<td>0.15</td>
<td>0.115</td>
<td>0.137</td>
<td>147.4 (c)</td>
</tr>
<tr>
<td>San Francisco</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>day 29+</td>
<td>30.90</td>
<td>13.59</td>
<td>6.76</td>
<td>9.13</td>
<td>1.42</td>
<td>0.27</td>
<td>0.20</td>
<td>0.154</td>
<td>0.186</td>
<td>185.9 (c)</td>
</tr>
<tr>
<td>BZ formula 1</td>
<td>14.62</td>
<td>7.35</td>
<td>1.51</td>
<td>4.83</td>
<td>0.93</td>
<td>0.15</td>
<td>0.12</td>
<td>0.11</td>
<td>0.076</td>
<td>91.5 (c)</td>
</tr>
<tr>
<td>BZ formula 2</td>
<td>29.2</td>
<td>14.5</td>
<td>3.0</td>
<td>9.6</td>
<td>2.1</td>
<td>0.32</td>
<td>0.25</td>
<td>0.15</td>
<td>0.21</td>
<td>181.0 (c)</td>
</tr>
<tr>
<td>BZ formula 3</td>
<td>23.86</td>
<td>12.76</td>
<td>2.57</td>
<td>7.23</td>
<td>1.30</td>
<td>0.22</td>
<td>0.17</td>
<td>0.115</td>
<td>0.15</td>
<td>154.0 (c)</td>
</tr>
<tr>
<td>BZ final</td>
<td>18.4</td>
<td>9.8</td>
<td>1.94</td>
<td>5.56</td>
<td>0.99</td>
<td>0.17</td>
<td>0.13</td>
<td>0.088</td>
<td>0.118</td>
<td>118.5</td>
</tr>
<tr>
<td>San Diego day</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>90-100</td>
<td>26.3</td>
<td>12.03</td>
<td>8.08</td>
<td>5.18</td>
<td>ua</td>
<td>0.16</td>
<td>0.12</td>
<td>ua</td>
<td>ua</td>
<td>161.3 (c)</td>
</tr>
<tr>
<td>San Diego Day</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>101-222</td>
<td>30.5</td>
<td>13.57</td>
<td>9.60</td>
<td>6.13</td>
<td>ua</td>
<td>0.19</td>
<td>0.14</td>
<td>ua</td>
<td>ua</td>
<td>183.9 (c)</td>
</tr>
<tr>
<td>San Diego Day</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>223-343</td>
<td>30.5</td>
<td>12.32</td>
<td>10.3</td>
<td>6.62</td>
<td>ua</td>
<td>0.21</td>
<td>0.15</td>
<td>ua</td>
<td>ua</td>
<td>177.5 (c)</td>
</tr>
<tr>
<td><strong>ua</strong> = unavailable.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

d. Feeding /intake
As a guideline, cubs should be fed 15-25% of their body weight per day not to exceed 5% per feeding. It is important to weigh the cub at the same time each day. Quantities can gradually taper off to 10-20% of body weight by 90 days of age. Initially, feedings should be offered around the clock, evenly spaced 2-3 hours apart. The feeding regime should be reflective of the cub’s health status. By 1 month of age feedings may be reduced to 5-7 times per day. Number of feedings should be gradually reduced until weaning.

Tables 13a-c provide information on intake and body mass from Day 1 through 40 weeks of age for four hand-reared cubs. Weight gains in the first weeks of life tended to be erratic for both BZ and SFZ cubs. Because of medical issues with BZ’s cub, weight gains were much slower than both SFZ and SDZ cubs. Weight gains for this cub improved as health improved. Tables 14a-c provide energy intake from formula for the same cubs. SFZ cub consumed an average of 0.155 kcals ME/g body mass per day for weeks 3-9, while BZ cub consumed 0.264 kcals ME/g body mass. During weeks 14-18 SDZ’s cubs were consuming on average 0.32-0.33 kcals ME/g body mass from formula, while the BZ cub was consuming 0.10 kcals ME/g body mass from formula. This difference is not unexpected as solid foods were a more substantial part of the BZ cub’s diet at that time.
A variety of human infant bottles have been used for hand-rearing polar bears including preemie and orthodontic “Nuk” nipples. Playtex nipples may prevent chafing of the cub’s nose. Elongated nipples and those designed for human infants with cleft palates have also been utilized. A hole in the nipple may need to be opened and this must be done very carefully to prevent aspiration of formula flowing too quickly. If necessary, a nasogastric tube can be used to provide nourishment for an ill cub. However close monitoring is essential to prevent infection at suture sites. Beginning at 90 days syringes have been used successfully to offer formula.

Table 13a Polar bear cub intake and body mass Days 1-30.

<table>
<thead>
<tr>
<th>Age (days)</th>
<th>Body mass (kg)</th>
<th>% Change in body mass</th>
<th>Formula intake (ml/day)</th>
<th>Formula intake as % of body mass</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SFZ</td>
<td>BZ</td>
<td>SFZ</td>
<td>BZ</td>
</tr>
<tr>
<td>1</td>
<td>0.645</td>
<td>56</td>
<td>8.7</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.585</td>
<td>-9.30</td>
<td>164</td>
<td>28.0</td>
</tr>
<tr>
<td>3</td>
<td>0.640</td>
<td>9.40</td>
<td>272</td>
<td>42.5</td>
</tr>
<tr>
<td>4</td>
<td>0.665</td>
<td>3.91</td>
<td>233</td>
<td>35.0</td>
</tr>
<tr>
<td>5</td>
<td>0.800</td>
<td>20.30</td>
<td>252</td>
<td>31.5</td>
</tr>
<tr>
<td>6</td>
<td>0.900</td>
<td>12.50</td>
<td>252</td>
<td>28.0</td>
</tr>
<tr>
<td>7</td>
<td>1.000</td>
<td>11.11</td>
<td>-3.84</td>
<td>252</td>
</tr>
<tr>
<td>8</td>
<td>1.020</td>
<td>2.00</td>
<td>1.31</td>
<td>224</td>
</tr>
<tr>
<td>9</td>
<td>1.140</td>
<td>11.76</td>
<td>8.03</td>
<td>222</td>
</tr>
<tr>
<td>10</td>
<td>1.220</td>
<td>7.02</td>
<td>2.52</td>
<td>206.5</td>
</tr>
<tr>
<td>11</td>
<td>1.280</td>
<td>4.92</td>
<td>-0.23</td>
<td>196</td>
</tr>
<tr>
<td>12</td>
<td>1.320</td>
<td>3.13</td>
<td>2.41</td>
<td>196</td>
</tr>
<tr>
<td>13</td>
<td>1.380</td>
<td>4.55</td>
<td>2.05</td>
<td>252</td>
</tr>
<tr>
<td>14</td>
<td>1.440</td>
<td>4.35</td>
<td>2.05</td>
<td>196</td>
</tr>
<tr>
<td>15</td>
<td>1.589</td>
<td>10.35</td>
<td>3.49</td>
<td>252</td>
</tr>
<tr>
<td>16</td>
<td>0.893</td>
<td>4.96</td>
<td>194</td>
<td>190</td>
</tr>
<tr>
<td>17</td>
<td>0.903</td>
<td>1.13</td>
<td>196</td>
<td>110</td>
</tr>
<tr>
<td>18</td>
<td>0.863</td>
<td>-4.41</td>
<td>196</td>
<td>128</td>
</tr>
<tr>
<td>19</td>
<td>0.883</td>
<td>2.25</td>
<td>196</td>
<td>160</td>
</tr>
<tr>
<td>20</td>
<td>0.862</td>
<td>-2.31</td>
<td>196</td>
<td>157</td>
</tr>
<tr>
<td>21</td>
<td>1.827</td>
<td>14.98</td>
<td>3.85</td>
<td>196</td>
</tr>
<tr>
<td>22</td>
<td>0.909</td>
<td>1.55</td>
<td>294</td>
<td>185</td>
</tr>
<tr>
<td>23</td>
<td>0.973</td>
<td>6.99</td>
<td>324</td>
<td>200</td>
</tr>
<tr>
<td>24</td>
<td>0.999</td>
<td>2.72</td>
<td>294</td>
<td>199</td>
</tr>
<tr>
<td>25</td>
<td>1.001</td>
<td>0.16</td>
<td>311</td>
<td>196</td>
</tr>
<tr>
<td>26</td>
<td>1.045</td>
<td>4.40</td>
<td>311</td>
<td>130</td>
</tr>
<tr>
<td>27</td>
<td>1.130</td>
<td>8.13</td>
<td>311</td>
<td>264</td>
</tr>
<tr>
<td>28</td>
<td>1.210</td>
<td>7.08</td>
<td>354</td>
<td>280</td>
</tr>
<tr>
<td>29</td>
<td>1.280</td>
<td>5.79</td>
<td>322</td>
<td>301</td>
</tr>
<tr>
<td>30</td>
<td>2.753</td>
<td>50.68</td>
<td>4.69</td>
<td>290</td>
</tr>
</tbody>
</table>

SFZ = San Francisco Zoo 1982-83. 0.1 cub BZ= Brookfield Zoo 1999-2000. 0.1 cub

Table 13b. Polar bear cub intake and body mass Days 31-60.

<table>
<thead>
<tr>
<th>Age (days)</th>
<th>Body mass (kg)</th>
<th>% Change in body mass</th>
<th>Formula Intake (ml/day)</th>
<th>Formula Intake as % of body weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SFZ</td>
<td>BZ</td>
<td>SFZ</td>
<td>BZ</td>
</tr>
<tr>
<td>31</td>
<td>1.405</td>
<td>4.85</td>
<td>269</td>
<td>335</td>
</tr>
<tr>
<td>SFZ = San Francisco Zoo 1982-83. 0.1 cub BZ= Brookfield Zoo 1999-2000. 0.1 cub</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 13c. Polar bear cub intake and body mass weeks 9-40

<table>
<thead>
<tr>
<th>Weeks of age</th>
<th>Body mass (kg)</th>
<th>Mean % change in body mass</th>
<th>Average formula intake (ml/day)</th>
<th>Average formula intake as % of body mass</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SFZ  BZ  SDM  SDF</td>
<td>SFZ  BZ  SDM  SDF</td>
<td>SFZ  BZ  SDM  SDF</td>
<td>SFZ  BZ  SDM  SDF</td>
</tr>
<tr>
<td>9</td>
<td>5.15</td>
<td>3.00</td>
<td>510  1018</td>
<td>19.8</td>
</tr>
<tr>
<td>10</td>
<td>6.36  6.25</td>
<td>25.86  21.36</td>
<td>510  1073</td>
<td>8.0  17.2</td>
</tr>
<tr>
<td>11</td>
<td>7.49  7.75</td>
<td>17.86  24.00</td>
<td>398  1192</td>
<td>5.3  15.4</td>
</tr>
<tr>
<td>12</td>
<td>7.83  8.95</td>
<td>4.55  15.48</td>
<td>448  1323</td>
<td>5.7  14.8</td>
</tr>
<tr>
<td>13</td>
<td>10.20</td>
<td>13.97</td>
<td>476  1211</td>
<td>11.9</td>
</tr>
<tr>
<td>14</td>
<td>11.93  8.88   7.48</td>
<td>16.91</td>
<td>1418  1882  1563</td>
<td>11.9  20.0  20.0</td>
</tr>
<tr>
<td>16</td>
<td>11.35  16.30  13.46  11.72</td>
<td>44.92  12.80  19.75  27.11</td>
<td>1824  2334  2007</td>
<td>11.2  20.0  20.0</td>
</tr>
<tr>
<td>17</td>
<td>19.05  18.20  15.82</td>
<td>16.87  35.22  34.98</td>
<td>1876  2833  2513</td>
<td>9.8  20.0  20.0</td>
</tr>
<tr>
<td>19</td>
<td>22.65  26.04  23.00</td>
<td>8.37  18.90  18.86</td>
<td>2159  3559  2787</td>
<td>9.5  18.0  18.0</td>
</tr>
<tr>
<td>20</td>
<td>25.00  30.70  26.00</td>
<td>10.38  17.90  13.04</td>
<td>2366  2792  2675</td>
<td>9.5  18.0  18.0</td>
</tr>
<tr>
<td>21</td>
<td>28.00  33.00  29.50</td>
<td>12.00  7.49  13.46</td>
<td>2623  3265  3492</td>
<td>9.4  14.4  14.4</td>
</tr>
<tr>
<td>22</td>
<td>31.00  36.00  33.50</td>
<td>10.71  9.09  13.56</td>
<td>2143  2875  3422</td>
<td>6.9  15.0  15.0</td>
</tr>
<tr>
<td>23</td>
<td>33.00  40.00  37.00</td>
<td>6.45  11.11  10.45</td>
<td>1784  3779  3891</td>
<td>5.4  15.0  15.0</td>
</tr>
<tr>
<td>24</td>
<td>33.50  45.00  41.5</td>
<td>1.52  12.50  12.16</td>
<td>1287  3965  4380</td>
<td>3.8  10.0  10.0</td>
</tr>
<tr>
<td>25</td>
<td>32.50  48.00  44.00</td>
<td>-2.99  6.67  6.02</td>
<td>942  4344  4017</td>
<td>2.9  10.0  10.0</td>
</tr>
<tr>
<td>26</td>
<td>36.80  53.00  48.5</td>
<td>13.23  10.42  10.23</td>
<td>687  4289  3957</td>
<td>1.9  8.0  8.0</td>
</tr>
<tr>
<td>27</td>
<td>38.20  59.50  53.00</td>
<td>3.80  12.26  9.28</td>
<td>504  4423  4030</td>
<td>1.3  8.0  8.0</td>
</tr>
<tr>
<td>28</td>
<td>41.40  66.50  58.00</td>
<td>8.38  11.76  9.43</td>
<td>369  4949  4406</td>
<td>0.9  8.0  8.0</td>
</tr>
<tr>
<td>29</td>
<td>41.40  71.00  61.50</td>
<td>0.00  6.77  6.03</td>
<td>289  5480  4783</td>
<td>0.7  8.0  8.0</td>
</tr>
<tr>
<td>30</td>
<td>46.00  78.00  65.50</td>
<td>11.11  9.86  6.50</td>
<td>5552  4512  5.0  5.0</td>
<td>5.0  5.0</td>
</tr>
<tr>
<td>31</td>
<td>47.30  79.50  66.00</td>
<td>2.83  1.92  0.76</td>
<td>3932  3289  5.0  5.0</td>
<td>5.0  5.0</td>
</tr>
<tr>
<td>32</td>
<td>50.50  83.00  68.00</td>
<td>6.77  4.40  3.03</td>
<td>4036  3346  5.0  5.0</td>
<td>5.0  5.0</td>
</tr>
<tr>
<td>33</td>
<td>50.50  87.00  71.50</td>
<td>0.00  4.82  5.15</td>
<td>4236  3482  5.0  5.0</td>
<td>5.0  5.0</td>
</tr>
<tr>
<td>34</td>
<td>55.00  91.50  74.00</td>
<td>8.91  5.17  3.50</td>
<td>4418  3625  5.0  5.0</td>
<td>5.0  5.0</td>
</tr>
<tr>
<td>35</td>
<td>55.90  95.50  76.50</td>
<td>1.64  4.37  3.38</td>
<td>4650  3750  5.0  5.0</td>
<td>5.0  5.0</td>
</tr>
<tr>
<td></td>
<td>36</td>
<td>37</td>
<td>38</td>
<td>39</td>
</tr>
<tr>
<td>---</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td></td>
<td>58.20</td>
<td>99.00</td>
<td>79.00</td>
<td>4.11</td>
</tr>
<tr>
<td></td>
<td>58.20</td>
<td>103.5</td>
<td>81.50</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>59.50</td>
<td>107.5</td>
<td>85.00</td>
<td>2.23</td>
</tr>
<tr>
<td></td>
<td>61.40</td>
<td>112.0</td>
<td>88.00</td>
<td>3.19</td>
</tr>
<tr>
<td></td>
<td>63.60</td>
<td>116.0</td>
<td>89.00</td>
<td>3.58</td>
</tr>
</tbody>
</table>

SFZ = San Francisco Zoo 1982-83. 0.1 cub  
SDM = San Diego Zoo 2001 1.0 cub 90 days of age at arrival  
BZ = Brookfield Zoo 1999-2000. 0.1 cub  
SDF = San Diego Zoo 2001 0.1 cub 90 days of age at arrival
Table 14a. Polar bear cub energy intake Day 1-30

<table>
<thead>
<tr>
<th>Age (days)</th>
<th>% Solids in Formula</th>
<th>Intake (ml/day)</th>
<th>Energy intake from formula (kcal ME/day)</th>
<th>Energy intake/g body mass (kcal ME/g)</th>
<th>SFZ</th>
<th>BZ</th>
<th>SFZ</th>
<th>BZ</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SFZ</td>
<td>BZ</td>
<td>SFZ</td>
<td>BZ</td>
<td>SFZ</td>
<td>BZ</td>
<td>SFZ</td>
<td>BZ</td>
</tr>
<tr>
<td>1</td>
<td>13.7</td>
<td>56</td>
<td>39.2</td>
<td>0.061</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>13.7</td>
<td>164</td>
<td>114.8</td>
<td>0.196</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>13.7</td>
<td>272</td>
<td>190.4</td>
<td>0.298</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>15.4</td>
<td>233</td>
<td>198.1</td>
<td>0.298</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>15.4</td>
<td>7.3</td>
<td>214.2</td>
<td>22.0</td>
<td>0.268</td>
<td>0.031</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>17.3</td>
<td>10.4</td>
<td>206.5</td>
<td>121.5</td>
<td>239.4</td>
<td>72.4</td>
<td>0.266</td>
<td>0.101</td>
</tr>
<tr>
<td>7</td>
<td>17.3</td>
<td>14.6</td>
<td>252</td>
<td>123.5</td>
<td>239.4</td>
<td>147.3</td>
<td>0.239</td>
<td>0.214</td>
</tr>
<tr>
<td>8</td>
<td>20.3</td>
<td>17.7</td>
<td>224</td>
<td>235</td>
<td>255.4</td>
<td>241.5</td>
<td>0.250</td>
<td>0.346</td>
</tr>
<tr>
<td>9</td>
<td>20.3</td>
<td>24.4</td>
<td>222</td>
<td>166</td>
<td>253.1</td>
<td>233.1</td>
<td>0.222</td>
<td>0.309</td>
</tr>
<tr>
<td>10</td>
<td>20.3</td>
<td>21.4</td>
<td>206.5</td>
<td>121.5</td>
<td>235.4</td>
<td>111.9</td>
<td>0.193</td>
<td>0.145</td>
</tr>
<tr>
<td>11</td>
<td>20.3</td>
<td>21.7</td>
<td>196</td>
<td>123.5</td>
<td>223.4</td>
<td>151.5</td>
<td>0.175</td>
<td>0.197</td>
</tr>
<tr>
<td>12</td>
<td>20.3</td>
<td>21.9</td>
<td>196</td>
<td>87</td>
<td>223.4</td>
<td>110.5</td>
<td>0.169</td>
<td>0.140</td>
</tr>
<tr>
<td>13</td>
<td>20.3</td>
<td>25.6</td>
<td>252</td>
<td>145</td>
<td>287.3</td>
<td>214.6</td>
<td>0.208</td>
<td>0.266</td>
</tr>
<tr>
<td>14</td>
<td>20.3</td>
<td>29.2</td>
<td>196</td>
<td>160</td>
<td>223.4</td>
<td>270.4</td>
<td>0.155</td>
<td>0.329</td>
</tr>
<tr>
<td>15</td>
<td>24.3</td>
<td>29.2</td>
<td>252</td>
<td>190</td>
<td>365.4</td>
<td>321.1</td>
<td>0.230</td>
<td>0.377</td>
</tr>
<tr>
<td>16</td>
<td>24.3</td>
<td>21.9</td>
<td>194</td>
<td>110</td>
<td>281.3</td>
<td>153.6</td>
<td>0.172</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>24.3</td>
<td>11.0</td>
<td>196</td>
<td>128</td>
<td>284.2</td>
<td>84.3</td>
<td>0.093</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>24.3</td>
<td>17.1</td>
<td>196</td>
<td>160</td>
<td>284.2</td>
<td>264.2</td>
<td>0.306</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>24.3</td>
<td>23.1</td>
<td>196</td>
<td>157</td>
<td>284.2</td>
<td>217.3</td>
<td>0.246</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>24.3</td>
<td>23.9</td>
<td>196</td>
<td>169</td>
<td>284.2</td>
<td>241.7</td>
<td>0.280</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>24.3</td>
<td>23.9</td>
<td>196</td>
<td>185</td>
<td>284.2</td>
<td>264.6</td>
<td>0.156</td>
<td>0.295</td>
</tr>
<tr>
<td>22</td>
<td>24.3</td>
<td>23.9</td>
<td>294</td>
<td>200</td>
<td>426.3</td>
<td>286.0</td>
<td>0.315</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>24.3</td>
<td>23.9</td>
<td>324</td>
<td>199</td>
<td>469.8</td>
<td>284.6</td>
<td>0.293</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>24.3</td>
<td>23.9</td>
<td>294</td>
<td>196</td>
<td>426.3</td>
<td>280.3</td>
<td>0.280</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>24.3</td>
<td>21.1</td>
<td>311</td>
<td>130</td>
<td>451.0</td>
<td>159.5</td>
<td>0.159</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>24.3</td>
<td>18.4</td>
<td>311</td>
<td>264</td>
<td>451.0</td>
<td>290.4</td>
<td>0.278</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>24.3</td>
<td>18.4</td>
<td>311</td>
<td>280</td>
<td>451.0</td>
<td>308.0</td>
<td>0.273</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>24.3</td>
<td>18.4</td>
<td>354</td>
<td>301</td>
<td>513.3</td>
<td>331.1</td>
<td>0.274</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>30.9</td>
<td>18.4</td>
<td>322</td>
<td>325</td>
<td>550.6</td>
<td>357.5</td>
<td>0.279</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>30.9</td>
<td>18.4</td>
<td>290</td>
<td>335</td>
<td>495.9</td>
<td>368.5</td>
<td>0.180</td>
<td>0.275</td>
</tr>
</tbody>
</table>

SFZ = San Francisco Zoo 1982-83. 0.1 cub
BZ = Brookfield Zoo 1999-2000. 0.1 cub
Table 14b. Polar bear cub energy intake Day 31-60

<table>
<thead>
<tr>
<th>Age (days)</th>
<th>% Solids in Formula</th>
<th>Intake (ml/day)</th>
<th>Energy intake from formula (kCals ME/day)</th>
<th>Energy intake/g body mass (kCals ME/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SFZ BZ</td>
<td>SFZ BZ</td>
<td>SFZ BZ</td>
<td>SFZ BZ</td>
</tr>
<tr>
<td>31</td>
<td>30.9 18.4</td>
<td>269 350</td>
<td>460.0 385.0</td>
<td>0.274</td>
</tr>
<tr>
<td>32</td>
<td>30.9 18.4</td>
<td>310 373</td>
<td>530.1 410.3</td>
<td>0.273</td>
</tr>
<tr>
<td>33</td>
<td>30.9 18.4</td>
<td>310 383</td>
<td>530.1 421.3</td>
<td>0.273</td>
</tr>
<tr>
<td>34</td>
<td>30.9 18.4</td>
<td>290 384</td>
<td>495.9 422.4</td>
<td>0.275</td>
</tr>
<tr>
<td>35</td>
<td>30.9 18.4</td>
<td>327 384</td>
<td>559.2 422.4</td>
<td>0.273</td>
</tr>
<tr>
<td>36</td>
<td>30.9 18.4</td>
<td>335 391</td>
<td>572.9 430.1</td>
<td>0.272</td>
</tr>
<tr>
<td>37</td>
<td>30.9 18.4</td>
<td>342 406</td>
<td>584.8 446.6</td>
<td>0.268</td>
</tr>
<tr>
<td>38</td>
<td>30.9 18.4</td>
<td>320 425</td>
<td>547.2 467.5</td>
<td>0.169 0.274</td>
</tr>
<tr>
<td>39</td>
<td>30.9 18.4</td>
<td>336 462</td>
<td>574.6 508.2</td>
<td>0.276</td>
</tr>
<tr>
<td>40</td>
<td>30.9 18.4</td>
<td>371 474</td>
<td>634.4 521.4</td>
<td>0.275</td>
</tr>
<tr>
<td>41</td>
<td>30.9 18.4</td>
<td>392 500</td>
<td>670.3 550.0</td>
<td>0.274</td>
</tr>
<tr>
<td>42</td>
<td>30.9 18.4</td>
<td>392 528</td>
<td>670.3 580.8</td>
<td>0.274</td>
</tr>
<tr>
<td>43</td>
<td>30.9 18.4</td>
<td>392 562</td>
<td>670.3 618.2</td>
<td>0.174 0.271</td>
</tr>
<tr>
<td>44</td>
<td>30.9 18.4</td>
<td>336 615</td>
<td>574.6 676.5</td>
<td>0.273</td>
</tr>
<tr>
<td>45</td>
<td>30.9 18.4</td>
<td>381 527</td>
<td>651.5 579.7</td>
<td>0.230</td>
</tr>
<tr>
<td>46</td>
<td>30.9 18.4</td>
<td>366 613</td>
<td>625.9 674.3</td>
<td>0.256</td>
</tr>
<tr>
<td>47</td>
<td>30.9 18.4</td>
<td>426 707</td>
<td>728.5 777.7</td>
<td>0.275</td>
</tr>
<tr>
<td>48</td>
<td>30.9 18.4</td>
<td>426 728</td>
<td>728.5 800.8</td>
<td>0.276</td>
</tr>
<tr>
<td>49</td>
<td>30.9 18.4</td>
<td>447 758</td>
<td>764.4 833.8</td>
<td>0.274</td>
</tr>
<tr>
<td>50</td>
<td>30.9 18.4</td>
<td>540 811</td>
<td>923.4 892.1</td>
<td>0.271</td>
</tr>
<tr>
<td>51</td>
<td>30.9 18.4</td>
<td>510 716</td>
<td>872.1 787.6</td>
<td>0.175 0.229</td>
</tr>
<tr>
<td>52</td>
<td>30.9 18.4</td>
<td>540 789</td>
<td>923.4 867.9</td>
<td>0.244</td>
</tr>
<tr>
<td>53</td>
<td>30.9 18.4</td>
<td>540 807</td>
<td>923.4 887.7</td>
<td>0.239</td>
</tr>
<tr>
<td>54</td>
<td>30.9 18.4</td>
<td>233 908</td>
<td>398.4 998.8</td>
<td>0.079 0.261</td>
</tr>
<tr>
<td>55</td>
<td>30.9 18.4</td>
<td>426 834</td>
<td>728.5 917.4</td>
<td>0.234</td>
</tr>
<tr>
<td>56</td>
<td>30.9 18.4</td>
<td>497 937</td>
<td>849.9 1030.7</td>
<td>0.261</td>
</tr>
<tr>
<td>57</td>
<td>30.9 18.4</td>
<td>360 858</td>
<td>615.6 943.8</td>
<td>0.219</td>
</tr>
<tr>
<td>58</td>
<td>30.9 18.4</td>
<td>396 976</td>
<td>677.2 1073.6</td>
<td>0.253</td>
</tr>
<tr>
<td>59</td>
<td>30.9 18.4</td>
<td>426 973</td>
<td>728.5 1070.3</td>
<td>0.238</td>
</tr>
<tr>
<td>60</td>
<td>30.9 18.4</td>
<td>426 1021</td>
<td>728.5 1123.1</td>
<td>0.242</td>
</tr>
</tbody>
</table>

SFZ = San Francisco Zoo 1982-83. 0.1 cub
BZ= Brookfield Zoo 1999-2000. 0.1 cub
<table>
<thead>
<tr>
<th>Weeks of age</th>
<th>% Solids in Formula</th>
<th>Intake (ml/day)</th>
<th>Energy intake from formula (kcal ME/day)</th>
<th>Energy intake/g body mass (kcal ME/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SFZ  BZ  SDM  SDF</td>
<td>SFZ  BZ  SDM  SDF</td>
<td>SFZ  BZ  SDM  SDF</td>
<td>SFZ  BZ  SDM  SDF</td>
<td>SFZ  BZ  SDM  SDF</td>
</tr>
<tr>
<td>9 30.9 18.4</td>
<td>510 1046</td>
<td>872.1 1150.6</td>
<td>0.223</td>
<td></td>
</tr>
<tr>
<td>10 30.9 18.4</td>
<td>510 1073</td>
<td>872.1 1180.5</td>
<td>0.137 0.180</td>
<td></td>
</tr>
<tr>
<td>11 30.9 18.9</td>
<td>398 1192</td>
<td>681.3 1329.3</td>
<td>0.102 0.167</td>
<td></td>
</tr>
<tr>
<td>12 30.9 19.6</td>
<td>448 1323</td>
<td>766.1 1500.4</td>
<td>0.098 0.156</td>
<td></td>
</tr>
<tr>
<td>13 30.9 20.2</td>
<td>476 1211</td>
<td>814.0 1399.0</td>
<td>0.172</td>
<td></td>
</tr>
<tr>
<td>14 21.1 26.3 26.3</td>
<td>1418 1882 1563</td>
<td>1672.5 3030.2 2517.1</td>
<td>0.177 0.323 0.316</td>
<td></td>
</tr>
<tr>
<td>15 21.6 29.9 29.9</td>
<td>1926 1972 1597</td>
<td>2306.4 3585.0 2901.1</td>
<td>0.160 0.352 0.358</td>
<td></td>
</tr>
<tr>
<td>16 24.0 30.5 30.5</td>
<td>1824 2334 2007</td>
<td>2317.8 4317.6 3712.2</td>
<td>0.151 0.359 0.354</td>
<td></td>
</tr>
<tr>
<td>17 25.5 30.5 30.5</td>
<td>1876 2833 2513</td>
<td>2476.7 5241.6 4649.3</td>
<td>0.129 0.356 0.370</td>
<td></td>
</tr>
<tr>
<td>18 25.5 30.5 30.5</td>
<td>1978 2279 2043</td>
<td>2610.6 1807.2 1619.5</td>
<td>0.127 0.249 0.241</td>
<td></td>
</tr>
<tr>
<td>19 25.5 30.5 30.5</td>
<td>2159 3559 2787</td>
<td>2850.4 6583.8 5156.3</td>
<td>0.134 0.283 0.241</td>
<td></td>
</tr>
<tr>
<td>20 25.5 30.5 30.5</td>
<td>2366 2792 2675</td>
<td>3123.7 5164.9 4948.5</td>
<td>0.130 0.135 0.177</td>
<td></td>
</tr>
<tr>
<td>21 25.5 30.5 30.5</td>
<td>2623 3265 3492</td>
<td>3462.5 5546.5 6461.0</td>
<td>0.130 0.110 0.236</td>
<td></td>
</tr>
<tr>
<td>22 24.5 30.5 30.5</td>
<td>2143 2875 3422</td>
<td>2756.9 5403.3 6330.2</td>
<td>0.086 0.161 0.216</td>
<td></td>
</tr>
<tr>
<td>23 21.9 30.5 30.5</td>
<td>1784 3779 3891</td>
<td>2151.3 6990.9 7197.6</td>
<td>0.056 0.168 0.222</td>
<td></td>
</tr>
<tr>
<td>24 21.9 30.5 30.5</td>
<td>1287 3965 4380</td>
<td>1551.6 7334.5 8103.3</td>
<td>0.040 0.144 0.181</td>
<td></td>
</tr>
<tr>
<td>25 21.9 30.5 30.5</td>
<td>942 4344 4017</td>
<td>1135.5 8036.9 7432.2</td>
<td>0.030 0.189 0.189</td>
<td></td>
</tr>
<tr>
<td>26 21.9 30.5 30.5</td>
<td>687 4289 3957</td>
<td>828.0 7933.9 7320.7</td>
<td>0.020 0.154 0.151</td>
<td></td>
</tr>
<tr>
<td>27 21.9 30.5 30.5</td>
<td>504 4423 4030</td>
<td>607.7 8182.3 7455.0</td>
<td>0.014 0.146 0.147</td>
<td></td>
</tr>
<tr>
<td>28 21.9 30.5 30.5</td>
<td>369 4949 4406</td>
<td>445.0 9155.4 8150.6</td>
<td>0.009 0.145 0.147</td>
<td></td>
</tr>
<tr>
<td>29 21.9 30.5 30.5</td>
<td>289 5480 4783</td>
<td>348.5 10138.0 8848.3</td>
<td>0.148 0.148</td>
<td></td>
</tr>
<tr>
<td>30 30.5 30.5</td>
<td>2552 4512</td>
<td>10271.5 8347.7</td>
<td>0.091 0.071</td>
<td></td>
</tr>
<tr>
<td>31 30.5 30.5</td>
<td>3932 3289</td>
<td>7274.5 6085.2</td>
<td>0.093 0.093</td>
<td></td>
</tr>
<tr>
<td>32 30.5 30.5</td>
<td>4036 3346</td>
<td>7343.8 6090.1</td>
<td>0.088 0.088</td>
<td></td>
</tr>
<tr>
<td>33 30.5 30.5</td>
<td>4236 3482</td>
<td>7539.6 6198.2</td>
<td>0.088 0.087</td>
<td></td>
</tr>
<tr>
<td>34 30.5 30.5</td>
<td>4418 3625</td>
<td>7863.8 6452.5</td>
<td>0.088 0.087</td>
<td></td>
</tr>
<tr>
<td>35 30.5 30.5</td>
<td>4650 3750</td>
<td>8277.0 6675.0</td>
<td>0.089 0.089</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30.5</td>
<td>30.5</td>
<td></td>
<td>4832</td>
</tr>
<tr>
<td>---</td>
<td>-------</td>
<td>-------</td>
<td>---</td>
<td>-------</td>
</tr>
<tr>
<td>37</td>
<td>30.5</td>
<td>30.5</td>
<td></td>
<td>5021</td>
</tr>
<tr>
<td>38</td>
<td>30.5</td>
<td>30.5</td>
<td></td>
<td>5232</td>
</tr>
<tr>
<td>39</td>
<td>30.5</td>
<td>30.5</td>
<td></td>
<td>5476</td>
</tr>
<tr>
<td>40</td>
<td>30.5</td>
<td>30.5</td>
<td></td>
<td>4028</td>
</tr>
</tbody>
</table>

SFZ = San Francisco Zoo 1982-83 0.1 cub  
SDM = San Diego Zoo 2001 1.0 cub 90 days of age at arrival  
BZ = Brookfield Zoo 1999-2000 0.1 cub  
SDF = San Diego Zoo 2001 0.1 cub 90 days of age at arrival  

39 of 65
e. Weaning
Polar bear cubs nurse for up to 2-3 years in the wild (Briggs, 2001). The age at which the contribution of nursing transitions from nutritional dependence to social bonding with the sow is unclear. Weaning in the wild involves both nutritional and behavioral processes, while captive weaning typically refers to cessation of bottle-feeding. The captive weaning off the bottle process (i.e. introduction to solids) can begin as early as 60 days, though 70-85 days is more common. Baby cereal, canned cat or dog food and ground cat or dog food have been mixed with formula to introduce solid foods. At 3 months, most cubs can be offered dog kibble or omnivore biscuit, ground or soaked foods can be added, then progressing to dry. Fish or fresh meats have been offered as early as 100-110 days. For cubs in this section, formula was discontinued between 3-11 months of age. The process should be gradual, with only one variable changing at a time so as to track cause/effect for any change.

Figure 6 provides growth curves for San Francisco (1-16 weeks), Brookfield (1-40 weeks) and San Diego (14-40 weeks) polar bear cubs.

Products:
Esbilac - Pet-Ag, 30W 432 Route 20 Elgin, IL 60120
Multi-milk – Pet-Ag, 30W 432 Route 20 Elgin, IL 60120
Enfamil – Meade Johnson Nutritional Division, Meade Johnson and Co., 2404 W. Pennsylvania St., Evansville, IN 47721

Figure 6. Growth curves for four polar bear cubs.
9. APPENDICES

a. age classification

Polar Bear Specialist Group - Age Class Definitions

COY  Birth to 1 year of age (cubs born within last 12 months)  COY is short for Cub of the year

Yearlings  Year 1-Year 2 of life  Two

Year Olds  Year 2-Year 3 of life

Three Year Olds  Year 3-Year 4 of life

** also note that everything from weaning AT 2 AND 1/3 YEARS of age through

4 years old is also categorized as SUBADULT

Sub Adults  ALL ANIMALS AGE 2, 3, AND 4

Adults  5 years and up Male and Female
<table>
<thead>
<tr>
<th>Food Category</th>
<th>Diets - Percent of the diet as fed</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Example 1</td>
<td>Example 2</td>
<td>Example 3</td>
<td>Example 4</td>
<td></td>
</tr>
<tr>
<td>Nutritionally complete dry diet</td>
<td>5</td>
<td>50</td>
<td>5</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Nutritionally complete raw diet</td>
<td>44.5</td>
<td>30</td>
<td>75</td>
<td>32.5</td>
<td></td>
</tr>
<tr>
<td>Fish</td>
<td>30</td>
<td>15</td>
<td>15</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Meat from Bones†</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Whole Prey</td>
<td>2.5</td>
<td>0</td>
<td>0</td>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td>Produce</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Misc (enrichment)</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Unit</th>
<th>Diets - Nutrient levels on a dry matter basis.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Minimum Dietary Recommendations Polar Bear*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Example 1</td>
</tr>
<tr>
<td>Protein</td>
<td>%</td>
<td>25</td>
</tr>
<tr>
<td>Fat</td>
<td>%</td>
<td>5-20</td>
</tr>
<tr>
<td>Taurine</td>
<td>%</td>
<td>0.1</td>
</tr>
<tr>
<td>Linoleic acid</td>
<td>%</td>
<td>1</td>
</tr>
<tr>
<td>Vitamin A</td>
<td>IU/g</td>
<td>5</td>
</tr>
<tr>
<td>Vitamin D₃</td>
<td>IU/g</td>
<td>1.8</td>
</tr>
<tr>
<td>Vitamin E</td>
<td>IU/kg</td>
<td>100</td>
</tr>
<tr>
<td>Thiamin</td>
<td>mg/kg</td>
<td>5</td>
</tr>
<tr>
<td>Riboflavin</td>
<td>mg/kg</td>
<td>4</td>
</tr>
<tr>
<td>Niacin</td>
<td>mg/kg</td>
<td>40</td>
</tr>
<tr>
<td>Pyridoxine</td>
<td>mg/kg</td>
<td>4</td>
</tr>
<tr>
<td>Folinic</td>
<td>mg/kg</td>
<td>0.5</td>
</tr>
<tr>
<td>Biotin</td>
<td>mg/kg</td>
<td>0.07</td>
</tr>
<tr>
<td>Vitamin B₁₂</td>
<td>mg/kg</td>
<td>0.02</td>
</tr>
<tr>
<td>Pantothenic acid</td>
<td>mg/kg</td>
<td>5</td>
</tr>
<tr>
<td>Choline</td>
<td>mg/kg</td>
<td>1200</td>
</tr>
<tr>
<td>Calcium</td>
<td>%</td>
<td>0.6</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>%</td>
<td>0.5</td>
</tr>
<tr>
<td>Magnesium</td>
<td>%</td>
<td>0.04</td>
</tr>
<tr>
<td>Potassium</td>
<td>%</td>
<td>0.6</td>
</tr>
<tr>
<td>Sodium</td>
<td>%</td>
<td>0.2</td>
</tr>
<tr>
<td>Iron</td>
<td>mg/kg</td>
<td>80</td>
</tr>
<tr>
<td>Zinc</td>
<td>mg/kg</td>
<td>97</td>
</tr>
<tr>
<td>Copper</td>
<td>mg/kg</td>
<td>10</td>
</tr>
<tr>
<td>Manganese</td>
<td>mg/kg</td>
<td>7.5</td>
</tr>
<tr>
<td>Iodine</td>
<td>mg/kg</td>
<td>1.5</td>
</tr>
<tr>
<td>Selenium</td>
<td>mg/kg</td>
<td>0.1</td>
</tr>
</tbody>
</table>
Example diets that meet suggested ranges (section 4 c) All stage $^a$Suggested minimum polar values complied by the polar bear nutrition working group. $^b$Iodine values for some ingredients in the database are missing.
<table>
<thead>
<tr>
<th></th>
<th>Minimum Dietary Recommendations Polar Bear&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein %</td>
<td>25</td>
<td>23</td>
<td>-</td>
</tr>
<tr>
<td>Fat %</td>
<td>5-20</td>
<td>5</td>
<td>-</td>
</tr>
<tr>
<td>Fiber %</td>
<td>-</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>Ash %</td>
<td>-</td>
<td>-</td>
<td>11.5</td>
</tr>
<tr>
<td>Linoleic acid %</td>
<td>1</td>
<td>1.8</td>
<td>-</td>
</tr>
<tr>
<td>Vitamin A IU/g</td>
<td>5</td>
<td>5.6</td>
<td>-</td>
</tr>
<tr>
<td>Vitamin D&lt;sub&gt;3&lt;/sub&gt; IU/g</td>
<td>1.8</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Vitamin E IU/kg</td>
<td>100</td>
<td>90</td>
<td>-</td>
</tr>
<tr>
<td>Thiamin mg/kg</td>
<td>5</td>
<td>12</td>
<td>-</td>
</tr>
<tr>
<td>Riboflavin mg/kg</td>
<td>4</td>
<td>7</td>
<td>-</td>
</tr>
<tr>
<td>Niacin mg/kg</td>
<td>40</td>
<td>90</td>
<td>-</td>
</tr>
<tr>
<td>Pyridoxine mg/kg</td>
<td>4</td>
<td>7</td>
<td>-</td>
</tr>
<tr>
<td>Folacin mg/kg</td>
<td>0.5</td>
<td>1.0</td>
<td>-</td>
</tr>
<tr>
<td>Biotin mg/kg</td>
<td>0.07</td>
<td>0.2</td>
<td>-</td>
</tr>
<tr>
<td>Vitamin B&lt;sub&gt;12&lt;/sub&gt; mg/kg</td>
<td>0.02</td>
<td>0.03</td>
<td>-</td>
</tr>
<tr>
<td>Pantothenic acid mg/kg</td>
<td>5</td>
<td>11</td>
<td>-</td>
</tr>
<tr>
<td>Choline mg/kg</td>
<td>1200</td>
<td>2000</td>
<td>-</td>
</tr>
<tr>
<td>Calcium %</td>
<td>0.6</td>
<td>1.0</td>
<td>-</td>
</tr>
<tr>
<td>Phosphorus %</td>
<td>0.5</td>
<td>0.8</td>
<td>-</td>
</tr>
<tr>
<td>Magnesium %</td>
<td>0.04</td>
<td>0.05</td>
<td>-</td>
</tr>
<tr>
<td>Potassium %</td>
<td>0.6</td>
<td>0.6</td>
<td>-</td>
</tr>
<tr>
<td>Sodium %</td>
<td>0.2</td>
<td>0.2</td>
<td>-</td>
</tr>
<tr>
<td>Iron mg/kg</td>
<td>80</td>
<td>90</td>
<td>-</td>
</tr>
<tr>
<td>Zinc mg/kg</td>
<td>97</td>
<td>200</td>
<td>-</td>
</tr>
<tr>
<td>Copper mg/kg</td>
<td>10</td>
<td>16</td>
<td>-</td>
</tr>
<tr>
<td>Manganese mg/kg</td>
<td>7.5</td>
<td>8.0</td>
<td>-</td>
</tr>
<tr>
<td>Iodine mg/kg</td>
<td>1.5</td>
<td>1.0</td>
<td>-</td>
</tr>
<tr>
<td>Selenium mg/kg</td>
<td>0.1</td>
<td>0.13</td>
<td>-</td>
</tr>
</tbody>
</table>
c. **Specifications for appropriate nutritionally complete foods** – when fed according the suggested ranges (5% minimum to 50% maximum of the diet as fed,

will result in meeting the target nutrient range.  

*Suggested minimum polar values complied by the polar bear nutrition working group.*
cification for appropriate nutritionally complete meat mix - when fed according

<table>
<thead>
<tr>
<th></th>
<th>Minimum Dietary Recommendations Polar Bear&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td>%</td>
<td>25</td>
<td>30</td>
</tr>
<tr>
<td>Fat</td>
<td>%</td>
<td>5</td>
<td>5.0</td>
</tr>
<tr>
<td>Fiber</td>
<td>%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ash</td>
<td>%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Linoleic acid</td>
<td>%</td>
<td>1</td>
<td>2.0</td>
</tr>
<tr>
<td>Vitamin A</td>
<td>IU/g</td>
<td>5</td>
<td>5.0</td>
</tr>
<tr>
<td>Vitamin D₃</td>
<td>IU/g</td>
<td>1.8</td>
<td>2.0</td>
</tr>
<tr>
<td>Vitamin E</td>
<td>IU/kg</td>
<td>100</td>
<td>300</td>
</tr>
<tr>
<td>Thiamin</td>
<td>mg/kg</td>
<td>5</td>
<td>11.0</td>
</tr>
<tr>
<td>Riboflavin</td>
<td>mg/kg</td>
<td>4</td>
<td>16.0</td>
</tr>
<tr>
<td>Niacin</td>
<td>mg/kg</td>
<td>40</td>
<td>200</td>
</tr>
<tr>
<td>Pyridoxine</td>
<td>mg/kg</td>
<td>4</td>
<td>20.0</td>
</tr>
<tr>
<td>Folacin</td>
<td>mg/kg</td>
<td>0.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Biotin</td>
<td></td>
<td>0.07</td>
<td>0.3</td>
</tr>
<tr>
<td>Vitamin B&lt;sub&gt;12&lt;/sub&gt;</td>
<td>mg/kg</td>
<td>0.02</td>
<td>0.08</td>
</tr>
<tr>
<td>Pantothenic acid</td>
<td>mg/kg</td>
<td>5</td>
<td>15.0</td>
</tr>
<tr>
<td>Choline</td>
<td>mg/kg</td>
<td>1200</td>
<td>2639</td>
</tr>
<tr>
<td>Calcium</td>
<td>%</td>
<td>0.6</td>
<td>0.7</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>%</td>
<td>0.5</td>
<td>0.6</td>
</tr>
<tr>
<td>Magnesium</td>
<td>%</td>
<td>0.04</td>
<td>0.07</td>
</tr>
<tr>
<td>Potassium</td>
<td>%</td>
<td>0.6</td>
<td>0.8</td>
</tr>
<tr>
<td>Sodium</td>
<td>%</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Iron</td>
<td>mg/kg</td>
<td>80</td>
<td>128</td>
</tr>
<tr>
<td>Zinc</td>
<td>mg/kg</td>
<td>97</td>
<td>110</td>
</tr>
<tr>
<td>Copper</td>
<td>mg/kg</td>
<td>10</td>
<td>15.0</td>
</tr>
<tr>
<td>Manganese</td>
<td>mg/kg</td>
<td>7.5</td>
<td>20.0</td>
</tr>
<tr>
<td>Iodine</td>
<td>mg/kg</td>
<td>1.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Selenium</td>
<td>mg/kg</td>
<td>0.1</td>
<td>0.5</td>
</tr>
</tbody>
</table>

the suggested ranges (30% minimum to 75% maximum) of the diet as fed, will result
in meeting the target nutrient range. *Suggested minimum polar values complied by

the polar bear nutrition working group.

e. Behavioral Enrichment
The manner of presentation of the prescribed diet should be varied for behavioral enrichment purposes (i.e. scattered, chopped vs. whole, presented in feeder balls or barrels, training sessions). Supplemental enrichment foods (i.e. raisins, peanut butter, honey etc.) may be offered but should vary and should not exceed (3% by weight) of the total diet offered. This is critical to providing a balanced diet. All food enrichment items should go through the approval process for your institutions, including review by nutritionists and veterinarian. All new items should be watched closely. Storage and handling of food enrichment items should follow the same standards as those for other diet ingredients.

f. Checklist for inspecting a meat/prey or fish shipment

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Are the documents in order?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Type and size of fish</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>B. Size of entire shipment: number of boxes/containers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. Quantity: total quantity by weight of shipment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. Freezing method: block - IQF – shatter pack E. Pricing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Is the packaging size correct?</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>3. If required, are the boxes dated?</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>4. If required, is there a history of the catch included?</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>5. Are there any nonfood items in the shipping vehicle?</td>
<td>YES</td>
<td>NO</td>
</tr>
</tbody>
</table>
6. Does the temperature gauge of the vehicle indicate frozen conditions inside?  
   YES  NO
7. Do the contents appear frozen?  
   YES  NO
8. Is there any evidence of thawing (and refreezing)?  
   A. Are there areas of ice under the boxes?  
   YES  NO  
   B. Are any of the boxes stained or distorted?  
   YES  NO

g. Quality control meat/prey standards

Quality control factors are used to determine fish quality during inspection and preparation. Although there is no ultimate test to determine the quality of fish, below is a compilation of descriptions of acceptable, inferior, and unacceptable fish (Frazier and Westhoff 1988, Oftedal and Boness 1983, Stoskopf 1986).

<table>
<thead>
<tr>
<th>Factor</th>
<th>Acceptable</th>
<th>Inferior</th>
<th>Unacceptable</th>
</tr>
</thead>
</table>
| General Appearance    | Meat: cherry red tissue  
                       | Prey: shine or luster to skin; no breaks in skin; no bloating or protrusion of viscera; no dehydration | Meat: some browning  
                       | Prey: some loss of sheen | Meat: brown, slimy  
                       | Prey: luster gone, lumpy |
| Eyes                  | Prey: translucent, full may be slightly sunken | Prey: dull or cloudy, slightly sunken | Prey: dull, sunken, cornea opaque (white); red-bordered eyes |
| Odor                  | Meat and prey: fresh odor | Meat and prey: mild sour odor | Meat and prey: medium to strong odor, putrid odor |
| Feel                  | Meat: firm and elastic; meat does not stay indented when touched  
                       | Prey: firm and elastic | Meat: moderate softness to touch if whole meat Prey: moderately soft, slight indentation left when touched | Meat: slimy, soft, mushy  
                       | Prey: soft, spongy, and flabby; exudes juice and easily indented when handled; may break open or skin may split when handled |

h. Quality control fish standards

Quality control factors are used to determine fish quality during inspection and preparation. Although there is no ultimate test to determine the quality of fish, below is a compilation of descriptions of acceptable, inferior, and unacceptable fish (Frazier and Westhoff 1988, Oftedal and Boness 1983, Stoskopf 1986).

<table>
<thead>
<tr>
<th>Factor</th>
<th>Acceptable</th>
<th>Inferior</th>
<th>Unacceptable</th>
</tr>
</thead>
</table>

51 of 70
<table>
<thead>
<tr>
<th>General Appearance</th>
<th>shine or luster to skin; no breaks in skin; no bloating or protrusion of viscera; no dehydration</th>
<th>some loss of sheen</th>
<th>luster gone, lumpy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eyes</td>
<td>translucent, full; may be slightly sunken</td>
<td>dull or cloudy, slightly sunken</td>
<td>dull, sunken; cornea opaque (white); red-bordered eyes</td>
</tr>
<tr>
<td>Gills</td>
<td>bright red to pink; moist</td>
<td>pink to slight brownish</td>
<td>grayish-yellow and covered with mucus</td>
</tr>
<tr>
<td>Odor</td>
<td>fresh odor</td>
<td>mild sour or &quot;fishy&quot; odor</td>
<td>medium to strong odor, fatty fish may smell rancid</td>
</tr>
<tr>
<td>Feel</td>
<td>firm and elastic; meat does not stay indented when touched</td>
<td>moderately soft, slight indentation left when touched</td>
<td>soft, spongy and flabby; exudes juice and easily indented when handled; may break open or skin may split when handled</td>
</tr>
<tr>
<td>Vent</td>
<td>normal in shape and color</td>
<td>slight protrusion</td>
<td>noticeable discoloration</td>
</tr>
<tr>
<td>Lateral line</td>
<td>normal, no discoloration</td>
<td>pinkish tinge</td>
<td>red to dark red</td>
</tr>
</tbody>
</table>

i. Feeding Schedule/Interval taken from a survey conducted by Celia Ackerman, from Central Park Wildlife Center – personal communication

<table>
<thead>
<tr>
<th>Institution</th>
<th>AM</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milwaukee County Zoo</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Baltimore Zoo</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Oregon Zoo</td>
<td>X+</td>
<td>X+</td>
</tr>
<tr>
<td>North Carolina Zoo</td>
<td>X</td>
<td>2X</td>
</tr>
<tr>
<td>San Diego Zoo</td>
<td>X+</td>
<td>X+</td>
</tr>
<tr>
<td>Sea World of California, San Diego</td>
<td>X+</td>
<td>X+</td>
</tr>
<tr>
<td>Toledo Zoo</td>
<td>X+</td>
<td>X+</td>
</tr>
<tr>
<td>San Francisco Zoological Gardens</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Indianapolis Zoo</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Buffalo Zoo</td>
<td>X+</td>
<td>X+</td>
</tr>
<tr>
<td>Cincinnati Zoo</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Louisville Zoo</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Henry Vilas Zoo</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Point Defiance Zoo and Aquarium</td>
<td>X</td>
<td>X+</td>
</tr>
<tr>
<td>Philadelphia Zoo</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Location</td>
<td>Feeds</td>
<td>Feeds</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>-------</td>
<td>-------</td>
</tr>
<tr>
<td>Brookfield Zoo</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Lincoln Park</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Saint Louis Zoo</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>St. Paul’s Como Zoo</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

X = feeds during this time with the “+” sign indicating multiple times during this time period.

j. Selected food products used at polar bear institutions for polar bear diets taken from a survey conducted by Celia Ackerman, from Central Park Wildlife Center

<table>
<thead>
<tr>
<th>Meat</th>
<th>Nutritionally Complete Food</th>
<th>Produce</th>
<th>Fish</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFS Carnivore</td>
<td>Mazuri Polar Bear</td>
<td>Apples</td>
<td>Herring</td>
<td></td>
</tr>
<tr>
<td>Nebraska Feline</td>
<td>Mazuri Omnivore</td>
<td>Melon</td>
<td>Capelin</td>
<td></td>
</tr>
<tr>
<td>Nebraska Beef</td>
<td>PMI Labdiet Canine Dog Food</td>
<td>Berries</td>
<td>Smelt</td>
<td>Cod Liver Oil</td>
</tr>
<tr>
<td>Nebraska Canine</td>
<td>Purina Dog Food Maintenance</td>
<td>Grapes</td>
<td>Mackerel</td>
<td>Menhaden Fish Oil</td>
</tr>
<tr>
<td>Dallas Crown Carnivore</td>
<td>Purina High Protein Chow</td>
<td>Pears</td>
<td>Salmon</td>
<td>Omega Fish Oil</td>
</tr>
<tr>
<td>Chunk Horsemeat</td>
<td>Purina Dog Food Light</td>
<td>Papaya</td>
<td>Trout</td>
<td></td>
</tr>
<tr>
<td>Milliken Feline Diet</td>
<td>IAMS Dog Food</td>
<td>Orange</td>
<td>Sardines</td>
<td></td>
</tr>
<tr>
<td>Natural Balance Carnivore</td>
<td>IAMS Weight Control Dog</td>
<td>Raisins</td>
<td>Whitefish</td>
<td></td>
</tr>
<tr>
<td>IAMS Eukanuba Maintenance Dog</td>
<td></td>
<td>Bean Sprouts</td>
<td>Squid</td>
<td>Knuckle Bones</td>
</tr>
<tr>
<td>Nutrena River Run Dog Food</td>
<td></td>
<td>Carrot</td>
<td>Halibut</td>
<td>Femur Bones</td>
</tr>
<tr>
<td>Exclusive Lamb/Rice Formula</td>
<td></td>
<td>Kale</td>
<td></td>
<td>Shank Bones</td>
</tr>
<tr>
<td>Central Nebraska Packing</td>
<td></td>
<td>Sweet</td>
<td></td>
<td>Oxtail</td>
</tr>
<tr>
<td>Omnivore</td>
<td></td>
<td>Potato/Yam</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dad’s Chunx Dog Food</td>
<td></td>
<td>Corn</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wayne Brand Dog Food</td>
<td></td>
<td>Acorn Squash</td>
<td>Rabbits</td>
<td></td>
</tr>
<tr>
<td>ZuPreem Omnivore Diet</td>
<td></td>
<td>Pumpkin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Various brands dog food –</td>
<td></td>
<td>Romaine</td>
<td></td>
<td>Browse</td>
</tr>
<tr>
<td>donations</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lettuce</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Celery</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hard-boiled Egg</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

k. From: Husbandry and pathology of polar bears in Swiss Zoos (Dollinger et al 1996)

BASEL ZOO

1970’s polar bears of Basel Zoo fed predominantly meat and fish; diet uniform all year around.

1973 cyclic food intake as in the wild was considered. Bigger rations were offered from spring to autumn, while less or even no food was given during the winter period.

1974 diet was enriched by the addition of salad, carrots, corn, sunflowers and during the summer, grass.
Now food intake is 8500 grams of in-bone beef or horse meat, 850 grams of cyprinid fish, 4500 grams vegetables (such as carrot, salad, or fennel), 750 grams apples, 150 grams bread, as well as eggs and dog pellets. Dog pellets contained 23% CP, 4% CF, 5% fat, and 14,000 IU/kg vitamin A. In the winter the females do not eat and the other bears’ intake is greatly reduced preferring, apples and vegetables to meat.

ZURICH
Polar bears receive one side of horse or cow ribs, beef or horse meat cuts with a lot of fat, salad, and carrots. Occasionally, old layer hens, marine fish and salted/spiced fish are given. From November on, intake is greatly reduced. The female turns vegetarian during the winter, while the male will eat some ribs with his salad and carrots during that time period.

1. Results on nutrition of the international polar bear survey 1999
(analysed by L.Kolter, Zoo Köln, Germany)
The survey was circulated with the annual questionnaire for the International Polar Bear Studbook in 1999.

The analyses were restricted to the answers returned by the European zoos. 36 (51%) of 70 zoos keeping polar bears in 1999 in Europe answered. 34 provided information on diets; 10 of them just qualitatively with yes or no concerning the food items (meat, fish, vegetables, fruits, other). Of 24 there are for most of the food items “amounts offered” available.

Summary from 34 zoo:
- Locations fasting their animals for at least 1 day/week: 39%
  1 zoo fasted twice, another 3 times/wk.
- Meat was offered daily (except fast days) 94%
  no meat 6%
  in most cases beef, in some cases in exchange with poultry, in one case just horse meat, in another pork.
- Fish was offered daily (except fast days) 91%
  Occasionally 9%
  fish offered: mostly herring, occasionally mackerel, white fish etc.
- Other food was offered daily (except fast days) 97%
  restricted to summer 3%
  other food: mostly vegetables, bread and fruits, occasionally commercial pelleted dog food or nuts, self mixed gruel
- Cod liver oil was offered at least during certain seasons either on a daily or every second day basis 35%
Average amount of food offered (kg/animal/d; fast days subtracted). Please note if ranges were given, the lowest amount was taken, which very often is the amount given to the females; in general the males got 1 or 2 kg more of meat, fish or others.

<table>
<thead>
<tr>
<th></th>
<th>Meat (n=24)</th>
<th>Other (n=22)</th>
<th>Fish (n=23)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average: all zoos</td>
<td>3.8 (range: 0.25 – 8.5)</td>
<td>3.3 (range: 0.5 – 9.4)</td>
<td>3.0 (range: 0.5 – 8.5)</td>
</tr>
<tr>
<td>Average: zoos with reprod.</td>
<td>4.0 (range: 0.25 – 8.5)</td>
<td>3.1 (range: 1 – 9.4)</td>
<td>3.0 (range: 0.3 – 8.5)</td>
</tr>
<tr>
<td>Average: zoos without reprod.</td>
<td>3.5 (range: 2 – 5)</td>
<td>3.5 (range: 0.5 – 5)</td>
<td>3.3 (range 0.5 – 6)</td>
</tr>
</tbody>
</table>

Authors of the survey interpreted the following: that there is no immediate relationship between feeding and reproduction. But the sample size is much too small for valid conclusions and does not differentiate between “regular breeding” and “just once”.

**Seasonality**

Of the 36 European zoos 92% answered to the question whether they vary the amount of food offered seasonally and when they increase respectively reduce the amount of food:

39% offer the same amount over the whole year
12% vary the amount of food according to appetite (without indicating the seasons) 48% vary the amount of food with season. There is a lot of inter-zoo variability concerning the timing of increasing or decreasing food:

| Number of European zoos varying the amount of food offered with season |
|---------------------------|------------------|------------------|
|                           | Increase | Decrease |
| Spring                    | 7        | 3       |
| Summer                    | 2        | 4       |
| Autumn                    | 3        | 5       |
| Winter                    | 2        | 4       |
| no information            | 2        | 0       |
| Total                     | 16       | 16      |

Breeding and seasonality of food intake

Breeding (production of offspring at least once) was recorded in 61% of the zoos.

Authors of the survey suggested that the season when food increase started (winter/spring) versus (summer/autumn) seemingly did not have an effect on the percentage of breeding: 56% (n=9) versus 60% (n=5). But the sample size is much too small to provide valid data, which would have to be differentiated for “regular breeding” and “breeding just once” and “successful breeding” including rearing

**m. Meat consumption by three adult polar bears at Cologne zoo in 1991**

Kolter, L. 1991

Three captive polar bears 1,2) which were fed a restricted diet at the Cologne Zoo were noted to lose body condition. There was concern that these bears were too thin entering the winter months. Kolter modified the diet and recorded intake patterns for the...
following year. Meat was offered ad lib and the fruit and vegetables were restricted to 1 kg per day. Daily intake of meat fluctuated greatly day to day. General trends in meat consumption were noted.

Meat consumption increased from March (2kg/ind/d) through May (7kg/ind/d) and tended to remain high in the summer months. Bears had days of very high meat intake, followed by a few days of low to moderate intake. Meat consumption declined in August and September. In October, the bears refused meat on most days; in November meat intake stopped completely. All three bears routinely refused to eat sheep. Body condition did improve in all three individuals. There was no evidence that coat condition was influenced by diet, but coat condition did improve later after one of the females was removed from the exhibit. Kolter concluded that: 1) Meat consumption appears to be under some endogenous control which may reflect a pattern of availability in the wild; and 2) Occasional hyperphagia of meat (tended to be once per four days) may resemble a pattern of successful kills in the wild.


<table>
<thead>
<tr>
<th>Crude Protein Consumed, % DMB, Female Polar Bears ONLY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>North</td>
</tr>
<tr>
<td>Midwest</td>
</tr>
<tr>
<td>Midwest</td>
</tr>
<tr>
<td>West</td>
</tr>
<tr>
<td>Southeast</td>
</tr>
<tr>
<td>Southwest</td>
</tr>
<tr>
<td>Average</td>
</tr>
<tr>
<td>Standard Deviation</td>
</tr>
<tr>
<td>Number of Animals</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Crude Protein Consumed, % DMB, Male Polar Bears ONLY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>North</td>
</tr>
<tr>
<td>Midwest</td>
</tr>
<tr>
<td>Midwest</td>
</tr>
<tr>
<td>Southeast</td>
</tr>
<tr>
<td>South</td>
</tr>
<tr>
<td>Average</td>
</tr>
<tr>
<td>Standard Deviation</td>
</tr>
<tr>
<td>Number of Animals</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Crude Fiber Consumed, % DMB, Female Polar Bears ONLY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
</tr>
<tr>
<td>---------------</td>
</tr>
</tbody>
</table>

56 of 70
<table>
<thead>
<tr>
<th>Location</th>
<th>Zoo</th>
<th>Fall</th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>North</td>
<td>Detroit</td>
<td>5.65</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Midwest</td>
<td>Lincoln Park</td>
<td>3.05</td>
<td>3.28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Midwest</td>
<td>Indianapolis</td>
<td>2.88</td>
<td>2.88</td>
<td></td>
<td></td>
</tr>
<tr>
<td>West</td>
<td>San Francisco</td>
<td>1.43</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Southeast</td>
<td>North Carolina</td>
<td>1.99</td>
<td></td>
<td>2.56</td>
<td></td>
</tr>
<tr>
<td>Southwest</td>
<td>Reid Park</td>
<td>3.56</td>
<td>3.60</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>4.68</td>
<td>2.43</td>
<td>3.28</td>
<td>2.56</td>
</tr>
<tr>
<td></td>
<td>Standard Deviation</td>
<td>1.45</td>
<td>1.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Number of Animals</td>
<td>5</td>
<td>8</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

### Crude Fiber Consumed, % DMB, Male Polar Bears ONLY

<table>
<thead>
<tr>
<th>Location</th>
<th>Zoo</th>
<th>Fall</th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>North</td>
<td>Detroit</td>
<td>7.49</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Midwest</td>
<td>Lincoln Park</td>
<td>15.34</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Midwest</td>
<td>Indianapolis</td>
<td>3.41</td>
<td>2.52</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Southeast</td>
<td>North Carolina</td>
<td>2.74</td>
<td>2.44</td>
<td></td>
<td></td>
</tr>
<tr>
<td>South</td>
<td>San Antonio</td>
<td>3.53</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>4.79</td>
<td>3.01</td>
<td>3.41</td>
<td>2.44</td>
</tr>
<tr>
<td></td>
<td>Standard Deviation</td>
<td>5.30</td>
<td>0.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Number of Animals</td>
<td>2</td>
<td>5</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

### Crude Fat Consumed, % DMB, Female Polar Bears ONLY

<table>
<thead>
<tr>
<th>Location</th>
<th>Zoo</th>
<th>Fall</th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>North</td>
<td>Detroit</td>
<td>15.50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Midwest</td>
<td>Lincoln Park</td>
<td>17.71</td>
<td>15.34</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Midwest</td>
<td>Indianapolis</td>
<td>23.21</td>
<td>21.62</td>
<td></td>
<td></td>
</tr>
<tr>
<td>West</td>
<td>San Francisco</td>
<td>20.36</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Southeast</td>
<td>North Carolina</td>
<td>23.90</td>
<td></td>
<td>24.92</td>
<td></td>
</tr>
<tr>
<td>Southwest</td>
<td>Reid Park</td>
<td>16.30</td>
<td>14.07</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>17.20</td>
<td>19.06</td>
<td>15.34</td>
<td>24.92</td>
</tr>
<tr>
<td></td>
<td>Standard Deviation</td>
<td>3.52</td>
<td>4.44</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Number of Animals</td>
<td>5</td>
<td>8</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

### Crude Fat Consumed, % DMB, Male Polar Bears ONLY

<table>
<thead>
<tr>
<th>Location</th>
<th>Zoo</th>
<th>Fall</th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>North</td>
<td>Detroit</td>
<td>12.29</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Midwest</td>
<td>Lincoln Park</td>
<td>15.19</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Midwest</td>
<td>Indianapolis</td>
<td>35.41</td>
<td>31.92</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Location</td>
<td>Zoo</td>
<td>Fall</td>
<td>Winter</td>
<td>Spring</td>
<td>Summer</td>
</tr>
<tr>
<td>---------------</td>
<td>-------------------</td>
<td>------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
</tr>
<tr>
<td>Southeast</td>
<td>North Carolina</td>
<td>21.97</td>
<td>23.41</td>
<td></td>
<td></td>
</tr>
<tr>
<td>South</td>
<td>San Antonio</td>
<td>11.03</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Average

- Southeast
  - North Carolina: 21.97
  - Average: 23.85
  - Standard Deviation: 16.35
  - Number of Animals: 2

<table>
<thead>
<tr>
<th>Location</th>
<th>Zoo</th>
<th>Fall</th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>South</td>
<td>San Antonio</td>
<td>11.03</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Average

- San Antonio: 11.03
- Average: 19.59
- Standard Deviation: 9.00
- Number of Animals: 5

Calcium Consumed, % DMB, Female Polar Bears ONLY

Calcium Consumed, % DMB, Male Polar Bears ONLY

<table>
<thead>
<tr>
<th>Location</th>
<th>Zoo</th>
<th>Fall</th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midwest</td>
<td>Lincoln Park</td>
<td>2.67</td>
<td>3.06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Midwest</td>
<td>Indianapolis</td>
<td>2.48</td>
<td>2.60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>West</td>
<td>San Francisco</td>
<td>1.03</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Southeast</td>
<td>North Carolina</td>
<td>2.49</td>
<td>2.17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Southwest</td>
<td>Reid Park</td>
<td>2.89</td>
<td>2.22</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Average

- Lincoln Park: 2.67
- Indianapolis: 2.03
- San Francisco: 1.03
- North Carolina: 2.49
- Reid Park: 2.89
- Average: 2.69
- Standard Deviation: 0.29
- Number of Animals: 2

<table>
<thead>
<tr>
<th>Location</th>
<th>Zoo</th>
<th>Fall</th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midwest</td>
<td>Lincoln Park</td>
<td>3.07</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Midwest</td>
<td>Indianapolis</td>
<td>2.03</td>
<td>2.21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Southeast</td>
<td>North Carolina</td>
<td>2.1</td>
<td>2.27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>South</td>
<td>San Antonio</td>
<td>2.15</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Average

- Lincoln Park: 3.07
- Indianapolis: 2.03
- North Carolina: 2.1
- San Antonio: 2.15
- Average: 2.03
- Standard Deviation: 0.27
- Number of Animals: 1

Phosphorus Consumed, % DMB, Female Polar Bears ONLY

<table>
<thead>
<tr>
<th>Location</th>
<th>Zoo</th>
<th>Fall</th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midwest</td>
<td>Lincoln Park</td>
<td>1.42</td>
<td>1.56</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Midwest</td>
<td>Indianapolis</td>
<td>1.64</td>
<td>1.67</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Location</th>
<th>Zoo</th>
<th>Fall</th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midwest</td>
<td>Lincoln Park</td>
<td>1.42</td>
<td>1.56</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Midwest</td>
<td>Indianapolis</td>
<td>1.64</td>
<td>1.67</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Location</th>
<th>Zoo</th>
<th>Fall</th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midwest</td>
<td>Lincoln Park</td>
<td>3.07</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Midwest</td>
<td>Indianapolis</td>
<td>2.03</td>
<td>2.21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Southeast</td>
<td>North Carolina</td>
<td>2.1</td>
<td>2.27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>South</td>
<td>San Antonio</td>
<td>2.15</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Average

- Lincoln Park: 3.07
- Indianapolis: 2.03
- North Carolina: 2.1
- San Antonio: 2.15
- Average: 2.03
- Standard Deviation: 0.27
- Number of Animals: 1
### Phosphorus Consumed, % DMB, Male Polar Bears ONLY

<table>
<thead>
<tr>
<th>Location</th>
<th>Zoo</th>
<th>Fall</th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midwest</td>
<td>Lincoln Park</td>
<td>1.54</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Midwest</td>
<td>Indianapolis</td>
<td>1.42</td>
<td>1.48</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Southeast</td>
<td>North Carolina</td>
<td>1.46</td>
<td></td>
<td>1.65</td>
<td></td>
</tr>
<tr>
<td>South</td>
<td>San Antonio</td>
<td>1.47</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>1.54</td>
<td>1.37</td>
<td>1.56</td>
<td>1.64</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td></td>
<td>0.14</td>
<td>0.25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of Animals</td>
<td></td>
<td>2</td>
<td>8</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

### Vitamin A Consumed, IU/g DMB, Female Polar Bears ONLY

<table>
<thead>
<tr>
<th>Location</th>
<th>Zoo</th>
<th>Fall</th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midwest</td>
<td>Lincoln Park</td>
<td>36.00</td>
<td>35.35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Midwest</td>
<td>Indianapolis</td>
<td>15.65</td>
<td>16.12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>West</td>
<td>San Francisco</td>
<td>45.45</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Southeast</td>
<td>North Carolina</td>
<td>25.66</td>
<td></td>
<td>19.97</td>
<td></td>
</tr>
<tr>
<td>Southwest</td>
<td>Reid Park</td>
<td>80.87</td>
<td>49.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>48.26</td>
<td>39.10</td>
<td>35.35</td>
<td>19.97</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td></td>
<td>46.12</td>
<td>16.79</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of Animals</td>
<td></td>
<td>2</td>
<td>8</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

### Vitamin A Consumed, IU/g DMB, Male Polar Bears ONLY

<table>
<thead>
<tr>
<th>Location</th>
<th>Zoo</th>
<th>Fall</th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midwest</td>
<td>Lincoln Park</td>
<td>32.23</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Midwest</td>
<td>Indianapolis</td>
<td>13.77</td>
<td>14.21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Southeast</td>
<td>North Carolina</td>
<td>20.97</td>
<td></td>
<td>22.72</td>
<td></td>
</tr>
<tr>
<td>South</td>
<td>San Antonio</td>
<td>21.21</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>13.77</td>
<td>19.71</td>
<td>32.23</td>
<td>22.72</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td></td>
<td>3.55</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of Animals</td>
<td></td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

### Vitamin D3 Consumed, IU/g DMB, Female Polar Bears ONLY

<table>
<thead>
<tr>
<th>Location</th>
<th>Zoo</th>
<th>Fall</th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midwest</td>
<td>Lincoln Park</td>
<td>32.23</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Midwest</td>
<td>Indianapolis</td>
<td>13.77</td>
<td>14.21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Southeast</td>
<td>North Carolina</td>
<td>20.97</td>
<td></td>
<td>22.72</td>
<td></td>
</tr>
<tr>
<td>South</td>
<td>San Antonio</td>
<td>21.21</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>13.77</td>
<td>19.71</td>
<td>32.23</td>
<td>22.72</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td></td>
<td>3.55</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of Animals</td>
<td></td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Location</td>
<td>Zoo</td>
<td>Fall</td>
<td>Winter</td>
<td>Spring</td>
<td>Summer</td>
</tr>
<tr>
<td>----------</td>
<td>-------------</td>
<td>------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
</tr>
<tr>
<td>Midwest</td>
<td>Lincoln Park</td>
<td>1.61</td>
<td>2.36</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Midwest</td>
<td>Indianapolis</td>
<td>5.63</td>
<td>5.95</td>
<td></td>
<td></td>
</tr>
<tr>
<td>West</td>
<td>San Francisco</td>
<td>1.48</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Southeast</td>
<td>North Carolina</td>
<td>3.02</td>
<td>2.24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Southwest</td>
<td>Reid Park</td>
<td>2.20</td>
<td>2.17</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Average**

<table>
<thead>
<tr>
<th>Location</th>
<th>Fall</th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midwest</td>
<td>3.92</td>
<td>2.42</td>
<td>2.36</td>
<td>2.24</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>2.43</td>
<td>1.58</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of Animals</td>
<td>2</td>
<td>8</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

**Vitamin D3 Consumed, IU/g DMB, Male Polar Bears ONLY**

<table>
<thead>
<tr>
<th>Location</th>
<th>Zoo</th>
<th>Fall</th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midwest</td>
<td>Lincoln Park</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Midwest</td>
<td>Indianapolis</td>
<td>4.25</td>
<td>4.40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Southeast</td>
<td>North Carolina</td>
<td>2.38</td>
<td>2.60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>South</td>
<td>San Antonio</td>
<td>3.17</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Average**

<table>
<thead>
<tr>
<th>Location</th>
<th>Fall</th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midwest</td>
<td>4.25</td>
<td>3.10</td>
<td>2.44</td>
<td>2.60</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.90</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of Animals</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

**Vitamin E Consumed, IU/kg DMB, Female Polar Bears ONLY**

<table>
<thead>
<tr>
<th>Location</th>
<th>Zoo</th>
<th>Fall</th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midwest</td>
<td>Lincoln Park</td>
<td>166.20</td>
<td>165.60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Midwest</td>
<td>Indianapolis</td>
<td>410.10</td>
<td>380.70</td>
<td></td>
<td></td>
</tr>
<tr>
<td>West</td>
<td>San Francisco</td>
<td>268.20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Southeast</td>
<td>North Carolina</td>
<td>330.20</td>
<td>401.90</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Southwest</td>
<td>Reid Park</td>
<td>212.60</td>
<td>263.20</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Average**

<table>
<thead>
<tr>
<th>Location</th>
<th>Fall</th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midwest</td>
<td>311.35</td>
<td>276.01</td>
<td>165.60</td>
<td>401.90</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>139.65</td>
<td>90.60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of Animals</td>
<td>2</td>
<td>8</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

**Vitamin E Consumed, IU/kg DMB, Male Polar Bears ONLY**

<table>
<thead>
<tr>
<th>Location</th>
<th>Zoo</th>
<th>Fall</th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midwest</td>
<td>Lincoln Park</td>
<td>166.30</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Midwest</td>
<td>Indianapolis</td>
<td>357.50</td>
<td>313.40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Southeast</td>
<td>North Carolina</td>
<td>275.9</td>
<td>373.40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>South</td>
<td>San Antonio</td>
<td>136.1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Average**

<table>
<thead>
<tr>
<th>Location</th>
<th>Fall</th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midwest</td>
<td>357.50</td>
<td>227.48</td>
<td>166.30</td>
<td>373.40</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>88.99</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
o. Areas of historical controversy

Vitamin A – There is speculation that lower concentrations of vitamin A in the livers of captive polar bears could be a factor in high mortality, low reproductive rates and coat problems. Therefore, many institutions have supplemented polar bear diets with vitamin A. Higashi and Senoo (2003) researched the hepatic cells of polar bears and determined that hepatic stellate cells have the capacity for storage. They can store 80% of the total vitamin A in the whole body as retinyl esters in lipid droplets in the cytoplasm, and play pivotal roles in regulation of vitamin A homeostasis. Researchers are suggesting that polar bears have the capacity to store large amounts of vitamin A (Higashi and Senoo 2003, Leighton et al. 1988). The fact that an animal consumes a certain nutrient in abundance in the wild is not evidence of a particularly high requirement for that nutrient. Like cats, it is apparent that polar bears have a high tolerance for vitamin A, but there are no data to support a high vitamin A requirement. Dietary concentrations of 8.91 to 15.65 IU/g dry matter basis have been fed for years with no apparent deficiencies; therefore, a dietary minimum vitamin A content of 5 IU/g dry matter in the diet is recommended. For serum nutrient value discussion please refer to section 6.

Thiamin and vitamin E supplementation – Due to the presence of fish in many polar bear diet, some institutions feel the need to supplement those diets with thiamin and vitamin E. This perceived need to supplement is based on the knowledge that thiamin and vitamin E are broken down in stored frozen fish (Geraci, 1978). However, supplementation of thiamin and vitamin E is based on diets that contain greater than 30% fish. If the diet contains less than 30% fish then other food items are most likely providing the needed nutrients. It is still best to analyze the total diet in question, including enrichment items, to determine the need of any supplementation. A safe approach would be to always supplement the fish portion of the diet, regardless of the inclusion rate of fish (30 mg thiamin and 100 IU vitamin E per kg fish offered). This would ensure a balanced diet even if/when content of fish in the diet fluctuates.

Salt – Because polar bears exist in marine environments, it is believed they will benefit from salt supplementation. Mazzaro et al (2003) have studied the effect of salt or no salt supplementation for penguins in fresh water exhibits as compared to those exhibited in a marine environment. They found no difference in blood metabolites and no health problems, concluding it is not necessary to supplement penguins even though they possess salt glands. There is no research that supports that polar bear require dietary salt supplementation.

Vitamin D and calcium – Due to a small number of reported fractures in captive polar bears, there is speculation that there is a need for supplementing vitamin D and calcium. However, the data presented are on a small percentage of bears and do not appear to give indication of compromised bone density. Providing supplementation in excess of suggested guidelines is not warranted for any life stage, including pregnant or nursing females.
Fat – Fat is by far the most energy dense dietary constituent. Captive polar bear’s do not have the high energy demands of free-ranging bears, therefore, care should be taken not to over feed fat as obesity is a concern. Further, the fact that an animal consumes certain fatty acids in abundance in the wild, does not necessarily indicate a particularly high requirement for those nutrients. Because free-ranging polar bears eat almost an exclusively marine-based diet, their fatty acid profile resembles that of marine fats which are high in long chain poly unsaturated fatty acids (PUFAs).

Dietary fatty acids are required for healthy coat conditions. Animals have needs for essential and non-essential fatty acids. The essential fatty acids are those the animal cannot make but needs to consume in the diet while the non-essential fatty acids are those that the animal can convert within the body. The diet of the dog should contain an adequate quantity of linoleic acid. The dog can synthesize the gamma-linolenic acid and arachidonic acid from linoleic acid. Dogs and cats require 3 essential fatty acids: linoleic, gamma-linolenic, and arachidonic acid (Case, 1999). The cat, however, cannot synthesize arachidonic acid and must receive it in the diet (Case et al, 2000).

The fatty acid composition of polar bears differed between captive and wild bears with captive bears possessing fewer unsaturated fatty acids (especially 16:1, 20:1, and 22:6 with almost no 22:5) and wild bears having an abundant quantity of 22:5 and 22:6 (Colby et al, 1993). Samples of seal muscle and blubber were relatively high in concentrations of long-chained unsaturated fatty acids (Hoppener et al, 1978; West et al, 1979). Marine products are good sources of long chain unsaturated fatty acids. Current balanced polar bear diets (see Table 4 for suggested ranges) including fats from marine sources (marine fish or fish fed marine sources) should fulfill fatty acids requirements without additional fatty acids supplements. Again, before any supplementation is offered the diet should be analyzed.

Dental issues – Specific food items, presentation and presentation order may all have implications for dental health in polar bears. Dry biscuits are likely better for dental health than soft diets. Bones should be fresh and pliable. Rawhides, ox tails and hides may have teeth cleansing properties. Synthetic hard bones, ice blocks, and hard frozen food items may contribute to tooth damage. Biscuits should be fed dry and attempts should be made to prevent bears from wetting them. It would seem that ground meat products are by far the worst culprit in the diet for stickiness therefore, the presentation order can potentially help in removing organic buildup.

Suggested Feeding Order:
1. Ground meat product or slab meat
2. Dry diet
3. Fish, vegetables
4. Bones, chew item (hide, carcass)

Salmonid Poisoning and Tapeworms

STATEMENT ON THE SAFETY OF FEEDING ANADROMOUS FISH TO
Fish are a standard part of polar bear diets in zoos and aquaria. Though most fish are frozen and thawed for feeding, some institutions have access to fresh fish such as salmon and trout. Recently, facilities have encouraged the feeding of live fish for enrichment purposes. In 1982 two polar bears living in a Pacific Northwest zoo were thought to have died of salmon poisoning. More recently, sunbears in a west coast zoo were treated for an active case of salmon poisoning. Concern for polar bear health has lead institutions to question the feeding of anadromous (fish that swim upstream) fish, like salmon and trout, which can carry the fluke and rickettsial organism responsible for the disease. Investigation of this issue has lead to new recommendations for feeding live or fresh anadromous fish from the Pacific Northwest to polar bears.

Salmon poisoning is caused by rickettsial agents, Neorickettsia helminthoeca and Neorickettsia elokominica, which live in the fluke Nanophyetus salmincola. This fluke is found only in the Pacific northwest because its host, the Oxytrema plicifer snail, can only live in the coastal areas of Washington, Oregon and northern California. This could include hatchery raised fish. All anadromous fish (AF) can be carriers of this fluke in these locations, but 99% of the fish found to be infested are salmon. Trout, bluegill, and even Pacific salamanders have also been found to carry the fluke with these Neorickettsia. The snails carrying the flukes are ingested by the fish, the fluke cercariae encyst in the muscle of the fish and a carnivore eats the fish and becomes infected if the fluke carries the rickettsia. The adult fluke penetrates the mucosal lining of the gut and releases/injects the rickettsial agent into the bloodstream of the host. This step is critical to initiating an infection. Dead flukes (in frozen or cooked fish) cannot spread the rickettsia causing salmon poisoning. Carnivores become infested because they are considered the natural host for the fluke. Normally they adapt to the presence of the fluke, the body can fight the rickettsial disease and the animal doesn’t succumb to the disease. It is reported that cats, raccoons, black bears and grizzly bears eat infested/infected fish but do not experience salmon poisoning (Hoggan, 2001). The canid family, though, is a well known exception where untreated rickettsial infections can act quickly and be fatal.

A paucity of salmon poisoning cases in wild or zoo housed ursids and recommendations from veterinary pathologist Dr. Foryet at Washington State University School of Veterinary Medicine have lead to some level of comfort in feeding fresh Pacific Northwest anadromous fish (PNWAF). The 1982 incidence in 2 female polar bears and the 2004 case in sunbears have raised some questions and will require further investigation. Until these cases are clarified, when feeding AF it is safest to feed fish that have been frozen through and through (3 days of freezing for large salmon – longer for larger fish) if they are harvested from any Pacific Northwest location. Anadromous fish from locations other than the Pacifica Northwest may be feed fresh if deemed fit for human consumption.

Detection and Diagnostics
If an institution is going to feed PNWAF fresh or live, it will be important to screen and de-worm bears for the fluke that carries *N. helminthoea* or *N. elokominica*. To detect *Nanophyetus* eggs (operculated ova) it is critical to use a floatation technique using a SUGAR solution NOT fecasol, which is traditionally used for fecal floatations. Fecal exams should then be performed on a monthly basis.

If it is suspected that an animal has salmon poisoning, diagnostics should include:

- a fine needle aspirate of enlarged lymph nodes is necessary to make the diagnosis. Giemasa stain of macrophages in lymph node aspirate will show intracytoplasmic rickettsial bodies.

Common symptoms of Salmon poisoning in canids:

- Vomiting
- Lack of appetite
- Fever
- Diarrhea
- Weakness
- Swollen lymph nodes
- Dehydration

Treatment:

- Antibiotic for the rickettsial organism,
  - Tetracycline 20 mg/kg PO Q 8 hr for 3 weeks  OR  Oxytetracyline 7 mg/kg IV Q 12 hr until PO can be tolerated.
  - OR Chloramphenicol 30 mg/kg PO IV Q 8hr  OR  Trimethoprim Sulfadiazine 15 mg/kg PO, SC Q 12 hr
  - OR Sulfadimethoxine/ormetoprim, initial dose 55 mg/kg PO, then 27.5 mg/kg daily
- Antiparasitic for the fluke  OR  Fenbendazole 50 mg/kg PO SID for 10-14 d
  - OR  Praziquantel/pyrantel/febental (Drontal Plus) used according to manufacturers recommendations. Recommendations in canids warn against using in pregnant animals, dogs less than 2 pounds or puppies less than 3 weeks of age.

p. Partial list of references on plants that may be deleterious to various animal species.


Poisonous Plants of North Carolina
http://www.ces.ncsu.edu/depts/hort/consumer/poison/poison.htm
United States Food and Drug Association Poisonous Plant Database
http://www.cfsan.fda.gov/~djw/plantox.html

Canada Poisonous Plants Information System

10. LITERATURE CITED


Hoggan, S. 2001. Salmon Poisoning Disease: Pet Health topics from the College of Veterinary Medicine, Washington State University. Via search on Veterinary Information Network on 24 February 2005


Kolter, L. Meat consumption by three adult polar bears at the Cologne zoo. 1991 unpublished manuscript.


U.S. Navy. 1965. Section IV: Inspection of subsistence items, article no. 1-37, Inspection of fish and shellfish; Section V: Storage and care of subsistence items, article no. 1-47, Fresh and frozen subsistence items; Section VI: Sanitary precautions to be observed when preparing and servicing food, article no. 1-56, Preparing and serving. In Manual of Naval Preventive Medicine. Naval Medical Department, Bethesda, MD.


11. ADDITIONAL WORK PLANNED
   a. quantify nutrient consumption and feeding related issues across seasons at institutions with the ability to monitor
   b. collaborate with field researchers to incorporate BIA into body condition charts
   c. gather information on body condition during preship physicals as well as collect blood samples for nutrient status

12. RESEARCH
   a. review projects in progress for consistent methods and avoidance of duplicate efforts, sharing information/resources, and collaboration
   b. inter species bear species taurine investigation
c. dental diet trials
d. establish serum norms