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

Released February 6, 2006 Foreward

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 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 indepth 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.

Stirling,I., and Archibald,W.R., 1977. Aspects of predation of seals by polar bears. J.Fish.Res.Board Can, Vol 34,pp1126-1129.

Association of American Feed Control Officials (AAFCO). 2004. Dog and Cat Nutrient Profiles. Published by The Association of American Feed Control Officials. Oxford, IN. Pp:128-143.

National Research Council. 2006. Nutrient Requirements of Cats and Dogs. National Academy Press, Washington, D.C. In Press.

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 kcals/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_{12}, folacin, pantothenic acid and less vitamin B_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).

Nutrient	Unit	Minimum Nutrient Profile **bold = require for repro/growth**		Minimum Dietary Recommendations[b]
		Cat	Dog	Polar Bear
Protein	%	26.0 (**30.0**)	18.0 (**22.0**)	25.0
Fat, min	%	9.0	5.0 (**8.0**)	5.0
Fat, max	%	-	8.0	20.0
Lysine	%	0.83 (**1.2**)	0.63 (**0.77**)	1.0
Methionine + Cystine	%	1.1	0.43 (**0.53**)	1.0
Methionine	%	0.62	-	0.55
Taurine	%	0.1	-	0.1
Linoleic Acid	%	0.5	1.0	1.0

Arachidonic	%	0.02	-	0.02
Vitamin A min	IU/g	5.0	5.0	5.0
Vitamin A max	IU/g	333[a]	50[a]	-
Vitamin D_3	IU/g	0.5	0.5	1.8
Vitamin E	IU/kg	30	50	100
Vitamin K	mg/kg	0.1	-	-
Thiamin	mg/kg	5.0	1.0	5.0
Riboflavin	mg/kg	4.0	2.2	4.0
Niacin	mg/kg	60.0	11.4	40.0
Pyridoxine	mg/kg	4.0	1.0	4.0
Folacin	mg/kg	0.8	0.18	0.5
Biotin	mg/kg	0.07	-	0.07
Vitamin B_{12}	mg/kg	0.02	0.022	0.02
Pantothenic acid	mg/kg	5.0	10.0	5.0
Choline	mg/kg	2400	1200	1200
Calcium	%	0.6 (**1.0**)	0.6 (**1.0**)	0.6
Phosphorus	%	0.5 (**0.8**)	0.5 (**0.8**)	0.5
Magnesium	%	0.04 (**0.08**)	0.04	0.04
Potassium	%	0.6	0.6	0.6
Sodium	%	0.2	0.06 (**0.3**)	0.2
Iron	mg/kg	80	80	80
Zinc	mg/kg	75	120	100
Copper	mg/kg	5.0 (**15.0**)	7.3	10
Manganese	mg/kg	7.5	5.0	7.5
Iodine	mg/kg	0.35	1.5	1.5
Selenium	mg/kg	0.1	0.11	0.1

i.

Table

1. Cat

and dog nutrient profile minimum for all stages compared to suggested dietary recommendations for polar bears levels on a dry matter basis[a] [a]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

Dry Matter Intake (DMI), in kg of Female Polar Bears ONLY						
Location	Bears	Zoo	Fall	Winter	Spring	Summer
Northwest	2	Oregon	1.98	1.49		
North	3	Detroit	1.8			
Midwest	2	Lincoln Park		3.43	2.56	
Midwest	3	Indianapolis	2.42	1.55		
West	3	San Francisco		1.04		
Southeast	2	North Carolina		1.47		2.42
Southwest	3	Reid Park	2.24	2.79		
Average			2.00	1.81	2.56	2.42
Standard Deviation			0.48	0.90		
Number of Animals			7	10	1	1
DMI, in kg of Male Polar Bears ONLY						
Location	Bears	Zoo	Fall	Winter	Spring	Summer
Northwest	1	Oregon	2.62	2.48		
North	1	Detroit	1.02			
Midwest	1	Lincoln Park			2.79	
Midwest	3	Indianapolis	3.32	3.97		
Southeast	3	North Carolina		3.96		2.87
South	2	San Antonio		3.95		
Average			2.32	3.71	2.79	2.87
Standard Deviation			1.18	0.69		
Number of Animals			3	6	1	1

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.

Food item	calculated kcal ME/g
Regular Dog Chunks, Dry[1]	4.06
Weight Control for Dogs, Dry[1] Omnivore,	3.85
Dry[2]	2.80
Zoo Carnivore Diet 5%[3] Fish	1.19
Analog[2]	1.15
Rabbit, whole	1.35
Trout, whole	1.09
Herring, whole	1.78
Mackeral, whole	1.00

[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.

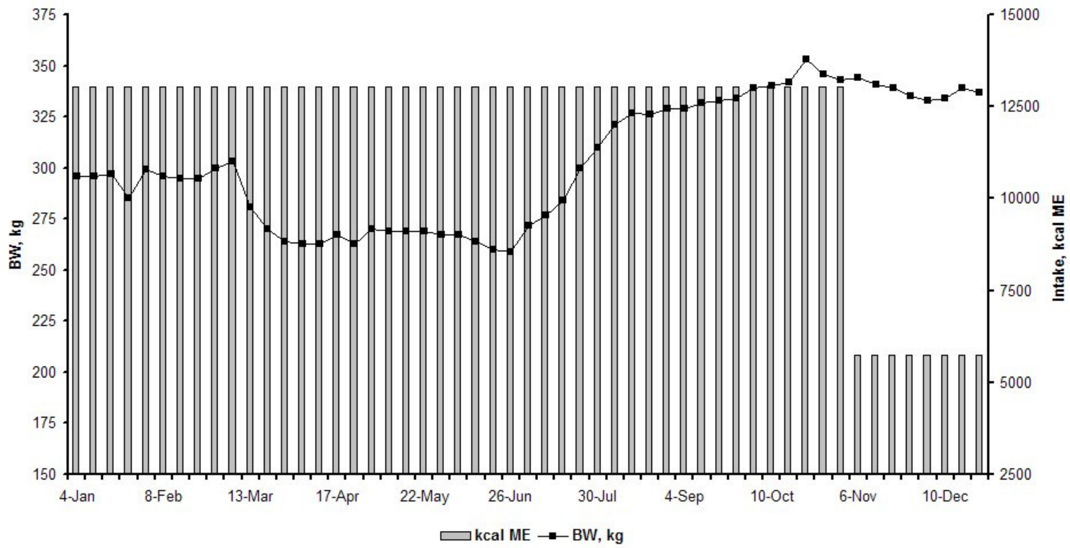


Figure 1. Changes in body weight (BW, kg) and total metabolizable energy intake (Intake, kcal ME) during 2004 in a three-year old, male polar bear housed in southern California.

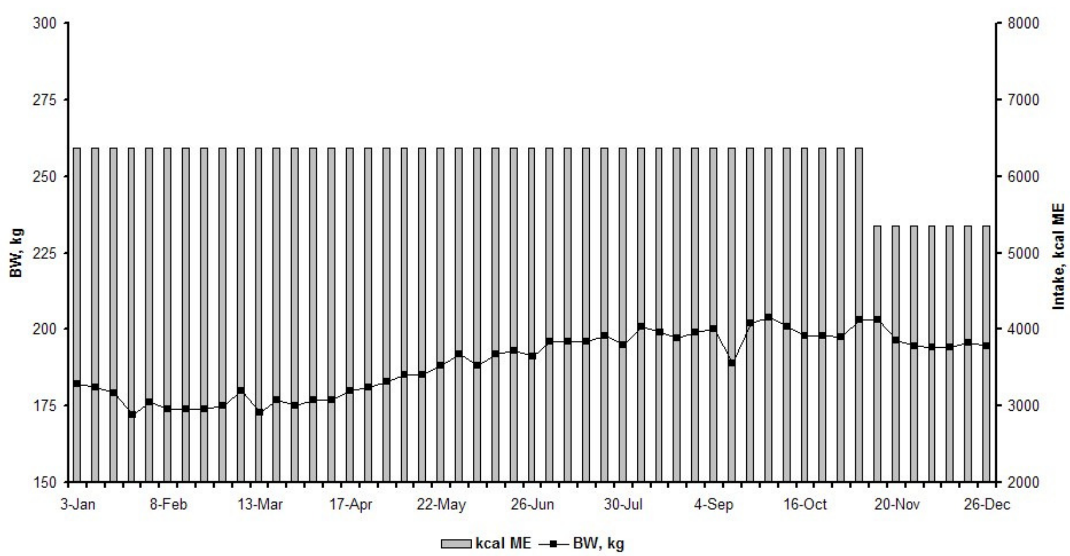


Figure 2. Changes in body weight (BW, kg) and total metabolizable energy intake (Intake, kcal ME) during 2004 in a three-year old, female polar bear housed in southern California.

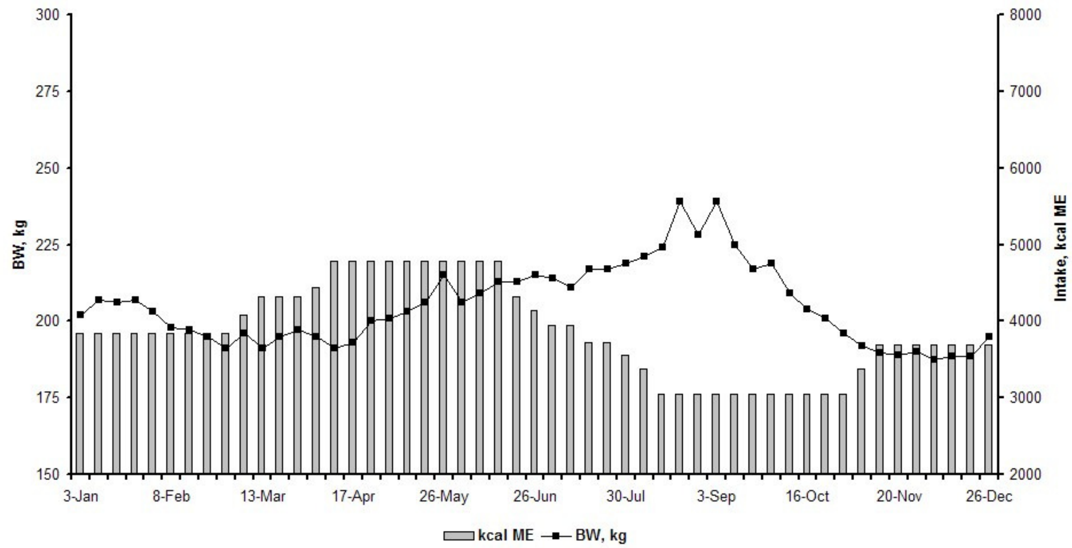


Figure 3. Changes in body weight (BW, kg) and total metabolizable energy intake (Intake, kcal ME) during 2004 in a nine-year old, female polar bear housed in southern California.

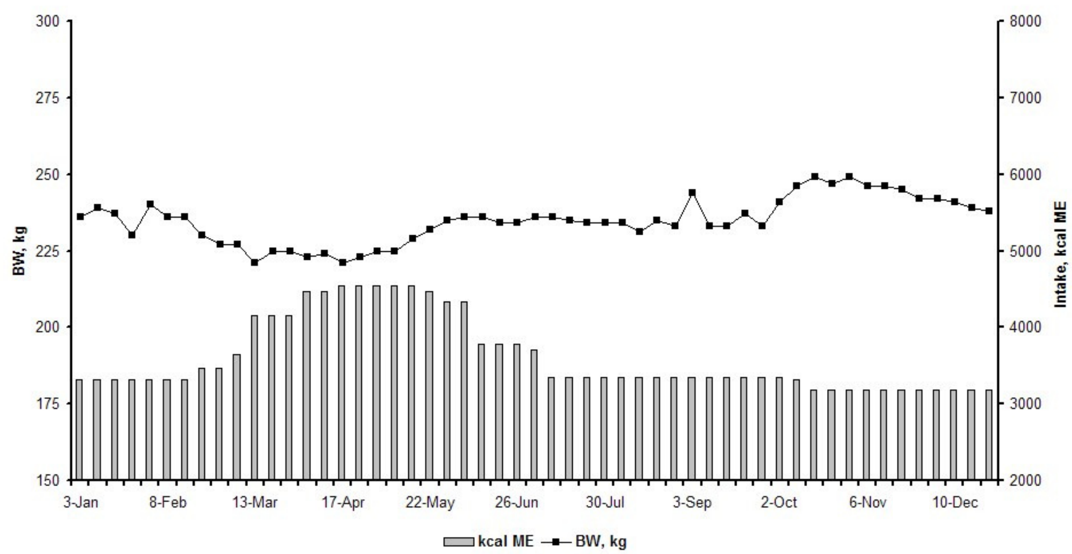


Figure 4. Changes in body weight (BW, kg) and total metabolizable energy intake (Intake, kcal ME) during 2004 in a nine-year old, female polar bear housed in southern California.

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 i. 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[1]

Ingredient	As Fed % of the Diet	
	Maintenance/Growth/Lactation	
	Minimum	Maximum
Dry Nutritionally Complete Food[2]	5	50
Raw Meat Mix Nutritionally Complete[3]	30	75
Marine Products – saltwater fish	15	30
Produce	0	10
Meat from Shank Bone[4]	5	7
Whole Prey[5]	0	2.5
Misc.[6]	0	3

[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

Ingredient	Brookfield Zoo, %	San Diego Zoo, %
Nutritionally complete dry diet	18.1	14.8
Nutritionally complete raw diet	26.8	36.2
Nutritionally complete gel diet	-	6.9
Saltwater Fish	23.6	15
Meat from Shank Bone	3.8	2.8
Whole Prey	-	8.0
Produce	27.7	16.3
Total	100	100

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

Nutrient	Unit	Levels on a Dry Matter Basis		
		Minimum Dietary Recommendations Polar Bear[a]	Brookfield Zoo diet offered[b]	San Diego Zoo[b]
Protein	%	25	35.3	43.8
Fat	%	5-20	14.0	16.9
Taurine	%	0.1	0.1	-
Linoleic acid	%	1	1.28	1.16
Vitamin A	IU/g	5	8.91	15.65
Vitamin D_3	IU/g	1.8	2.18	2.12
Vitamin E	IU/kg	100	165	289.4
Thiamin	mg/kg	5	5.33	10.1
Riboflavin	mg/kg	4	5.57	11.1
Niacin	mg/kg	40	52.45	53
Pyridoxine	mg/kg	4	5.23	5.4
Folacin	mg/kg	0.5	0.79	1.2
Biotin	mg/kg	0.07	0.07	--
Vitamin B_{12}	mg/kg	0.02	0.02	--
Pantothenic acid	mg/kg	5	4.11	23
Choline	mg/kg	1200	1149	1920
Calcium	%	0.6	2.03	1.43
Phosphorus	%	0.5	1.44	1.24
Magnesium	%	0.04	0.1	0.108
Potassium	%	0.6	1.16	0.899
Sodium	%	0.2	0.62	0.432
Iron	mg/kg	80	136	199.8
Zinc	mg/kg	97	119.2	111.1

Copper	mg/kg	10	13.3	25.5
Manganese	mg/kg	7.5	11.56	38.0
Iodine	mg/kg	1.5	--	2.55
Selenium	mg/kg	0.1	0.15	0.39

[a]Suggested minimum polar values complied by the polar bear nutrition working group. [b]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 then 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 fleshed, 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

(Information summarized from Crissey, S.D., K.A. Slifka, P. Shumway, and S.B. Spencer. 2001. Handling Frozen/Thawed Meat and Prey Items Fed to Captive Exotic Animals: A Manual of Standard Operating Procedures. U.S. Department of Agriculture, Agricultural Research Service, National Agricultural Library.)

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

(Information taken directly from Crissey, S.D. 1998. Handling Fish Fed to Fish-Eating Animals: A Manual of Standard Operating Procedures. U.S. Department of Agriculture, Agricultural Research Service, National Agricultural Library.)

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.

<u>Identifying the product</u>

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.

<u>Storage of the product</u>

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)

1 Pelvis and scapulae protruding, ribs easily palpated. A deep hollow will be noted between the pelvis and last rib showing virtually no fat.	**2** 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.	**3** 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.	**4** Bear has a rounded or blocky appearance, very well fleshed over all bony areas, obvious fat over rump and shoulders.	**5** Legs appear too short for the body, rolls of fat on neck and lower shoulders.

<u>b. BIA – </u>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]

[1]adaptation of Determination of Body Composition of Black and Brown Bears (1998), G.V.Hilderbrand, C.T. Robbins and S.D. Farley.

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 Vaccutainer® 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 (SVL^2/STAILR) + 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.

Nutrients	Crissey (2001)		Kenny (1998)				Schweigert (1990)	
	Captive		Captive		Free-ranging		Captive	
	N	Value ±SD	n	Value ±SD	N	Value ±SD	n	Value ±SD
25(OH)D, ng/ml	5	64±11	36	139±86	56	144±54	-	ua
1,25(OH)2D, pg/ml	5	18±4.2	-	ua	-	ua	-	ua
Retinol, µg/dl	4	25±1.8					1	67
Retinyl palmitate, µg/dl	4	4.9±1.3	-	ua	-	ua	-	Trace
Retinyl stearate, µg/dl	4	2.9±0.8	-	ua	-	ua	-	Trace
α-tocopherol, µg/dl	4	3362±193	32	800±800	56	2101±600	1	1459
γ-tocopherol, µg/dl	4	40±5.8	-	ua	-	ua	-	ua

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$(OH)_2$D 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 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.

	Crissey (2004)		Brannon (1985)		Schweigert (1990)	
Nutrients	N	Value ±SEM	N	Value ±SEM	N	Value ±SEM
Total cholesterol, mmol/L	6	8.9±0.76	29-35	5.2±0.24	1	5.7
Triacylglyceride, mmol/L	6	2.91±0.48	29-35	2.21±0.14	1	2.94
HDL cholesterol, mmol/L	6	5.8±0.37	-	ua	-	ua
LDL cholesterol, mmol/L	5	6.8±1.49	-	ua	-	ua

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.

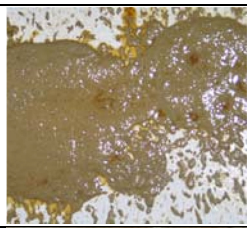
SCORE 0	Very loose, no form, possibly blood

SCORE 25	Mixture of formed and unformed, mostly loose

SCORE 50	Formed feces, but very soft

a. Figure 5. Fecal condition chart

SCORE 75	Formed, drier, but not hard




SCORE 100	Formed, but very hard

8. HAND REARING



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

Milestone	Age (days)
Eyes open	24-42
Incisors erupt 36-53 Canines erupt	46-53
Stand	60-82

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.

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

[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)

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

* 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

Item	Amount/100g (g)
Esbilac powder 11.6 Boiled water	88.4
Liquid pediatric vitamins	0.5 ml
Karo Syrup	4 ml

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

Day 6-7 Esbilac 1:2.5 water by volume

Item	Amount/100g (g)
Esbilac powder	14.0
Boiled water	86.0
Liquid pediatric vitamins	0.5 ml
Karo Syrup	4 ml

Added cod liver oil at 5 ml/day

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

Item	Amount/100g (g)
Esbilac powder	16.4
Boiled water	83.6
Liquid pediatric vitamins	0.5 ml
Karo Syrup	4 ml

Added cod liver oil at 5 ml/day

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

Item	Amount/100g (g)
Esbilac powder	20.8
Boiled water	80.3
Liquid pediatric vitamins	0.5 ml
Karo Syrup	4 ml

Added cod liver oil at 5 ml/day

Day 29+ 1:1 Esbilac:water by volume

Item	Amount/100g (g)
Esbilac powder	28.2
Boiled water	71.8
Liquid pediatric vitamins	0.5 ml
Karo Syrup	4 ml
Neo-Calglucon	2.5 ml

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

Item	Amount/100g (g)
Esbilac powder	7.5
Multi-milk powder	7.5
Boiled water	85
Liquid pediatric vitamins (Poly-vi-sol)	1 drop
Liquid iron supplement (Fer-in-sol)	1 drop
Lactaid	3 drops

Formula 2 Day 8-17*

Item	Amount/100g (g)
Esbilac powder	15
Multi-milk powder	15
Boiled water	70
Liquid pediatric vitamins (Poly-vi-sol)	1 drop
Liquid iron supplement (Fer-in-sol)	1 drop
Lactaid	3 drops

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

Formula 3 Day 18-24

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

Final formula used: Day 25 +

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

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

Day 90-100

Ingredients	Amount g/100 g
Esbilac Powder	11.5
Enfamil Powder	11.5
Corn Oil	4
Water	73

Day 101-222

Ingredients	Amount g/100 g
Esbilac Powder	13.5
Enfamil Powder	13.5
Corn Oil	4
Water	69

Day 223-343

Ingredients Amount g/100

	g
Esbilac Powder	14.5
Enfamil Powder	14.5
Corn Oil	2
Water	69

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

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

ua = unavailable.

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 90days 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.

Age (days)	Body mass (kg)		% Change in body mass		Formula intake (ml/day)		Formula intake as % of body mass	
	SFZ	BZ	SFZ	BZ	SFZ	BZ	SFZ	BZ
1	0.645				56		8.7	
2	0.585		-9.30		164		28.0	
3	0.640		9.40		272		42.5	
4	0.665		3.91		233		35.0	
5	0.800	0.710	20.30		252		31.5	
6	0.900	0.716	12.50	0.85	252		28.0	
7	1.000	0.689	11.11	-3.84	252	120	25.2	17.4
8	1.020	0.698	2.00	1.31	224	174	22.0	24.9
9	1.140	0.754	11.76	8.03	222	235	19.5	31.2
10	1.220	0.773	7.02	2.52	206.5	166	16.9	21.5
11	1.280	0.771	4.92	-0.23	196	121.5	15.3	15.8
12	1.320	0.789	3.13	2.41	196	123.5	14.8	15.6
13	1.380	0.806	4.55	2.05	252	87	18.3	10.8
14	1.440	0.822	4.35	2.05	196	145	13.6	17.6
15	1.589	0.851	10.35	3.49	252	160	15.9	18.8
16		0.893		4.96	194	190		21.3
17		0.903		1.13	196	110		12.2
18		0.863		-4.41	196	128		14.8
19		0.883		2.25	196	160		18.1
20		0.862		-2.31	196	157		18.2
21	1.827	0.895	14.98	3.85	196	169	10.7	18.9
22		0.909		1.55	294	185		20.3
23		0.973		6.99	324	200		20.6
24		0.999		2.72	294	199		19.9
25		1.001		0.16	311	196		19.6
26		1.045		4.40	311	130		12.4
27		1.130		8.13	311	264		23.4
28		1.210		7.08	354	280		23.1
29		1.280		5.79	322	301		23.5
30	2.753	1.340	50.68	4.69	290	325	10.5	24.3

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.

Age (days)	Body mass (kg)		% Change in body mass		Formula Intake (ml/day)		Formula Intake as % of body weight	
	SFZ	BZ	SFZ	BZ	SFZ	BZ	SFZ	BZ
31		1.405		4.85	269	335		23.8

32		1.505		7.12	310	350		23.3
33		1.545		2.66	310	373		24.1
34		1.535		-0.65	290	383		25.0
35		1.545		0.65	327	384		24.9
36		1.580		2.27	335	384		24.3
37		1.665		5.38	342	391		23.5
38	3.234	1.705	17.47	2.40	320	406	9.9	23.8
39		1.840		7.92	336	425		23.1
40		1.895		2.99	371	462		24.4
41		2.010		6.07	392	474		23.6
42		2.120		5.47	392	500		23.6
43	3.859	2.280	19.33	7.55	392	528	10.2	23.2
44		2.480		8.77	336	562		22.7
45		2.525		1.81	381	615		24.4
46		2.630		4.16	366	527		20.0
47		2.825		7.41	426	613		21.7
48		2.900		2.65	426	707		24.4
49		3.040		4.83	447	728		23.9
50		3.290		8.22	540	758		23.0
51	4.994	3.435	81.40	4.41	510	811	10.2	23.6
52		3.555		3.49	540	716		20.1
53		3.715		4.50	540	789		21.2
54	5.050	3.825	1.12	2.96	233	807	4.6	21.1
55		3.92		2.48	426	908		23.2
56		3.95		0.77	497	834		21.1
57		4.3		8.86	360	937		21.8
58		4.25		-1.16	396	858		20.2
59		4.5		5.88	426	976		21.7
60		4.65		3.33	426	973		20.9

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

Table 13c. Polar bear cub intake and body mass weeks 9-40

Weeks of age	Body mass (kg)				Mean % change in body mass				Average formula intake (ml/day)				Average formula intake as % of body mass			
	SFZ	BZ	SDM	SDF	SFZ	BZ	SDM	SDF	SFZ	BZ	SDM	SDF	SFZ	BZ	SDM	SDF
9		5.15				3.00			510	1018				19.8		
10	6.36	6.25			25.86	21.36			510	1073			8.0	17.2		
11	7.49	7.75			17.86	24.00			398	1192			5.3	15.4		
12	7.83	8.95			4.55	15.48			448	1323			5.7	14.8		
13		10.20				13.97			476	1211				11.9		
14		11.93	8.88	7.48		16.91				1418	1882	1563		11.9	20.0	20.0
15		14.45	11.24	9.22		21.17	26.58	23.26		1926	1972	1597		13.3	20.0	20.0
16	11.35	16.30	13.46	11.72	44.92	12.80	19.75	27.11		1824	2334	2007		11.2	20.0	20.0
17		19.05	18.20	15.82		16.87	35.22	34.98		1876	2833	2513		9.8	20.0	20.0
18		20.90	21.90	19.35		9.71	20.33	22.31		1978	2279	2043		9.5	20.0	20.0
19		22.65	26.04	23.00		8.37	18.90	18.86		2159	3559	2787		9.5	18.0	18.0
20		25.00	30.70	26.00		10.38	17.90	13.04		2366	2792	2675		9.5	18.0	18.0
21		28.00	33.00	29.50		12.00	7.49	13.46		2623	3265	3492		9.4	14.4	14.4
22		31.00	36.00	33.50		10.71	9.09	13.56		2143	2875	3422		6.9	15.0	15.0
23		33.00	40.00	37.00		6.45	11.11	10.45		1784	3779	3891		5.4	15.0	15.0
24		33.50	45.00	41.5		1.52	12.50	12.16		1287	3965	4380		3.8	10.0	10.0
25		32.50	48.00	44.00		-2.99	6.67	6.02		942	4344	4017		2.9	10.0	10.0
26		36.80	53.00	48.5		13.23	10.42	10.23		687	4289	3957		1.9	8.0	8.0
27		38.20	59.50	53.00		3.80	12.26	9.28		504	4423	4030		1.3	8.0	8.0
28		41.40	66.50	58.00		8.38	11.76	9.43		369	4949	4406		0.9	8.0	8.0
29		41.40	71.00	61.50		0.00	6.77	6.03		289	5480	4783		0.7	8.0	8.0
30		46.00	78.00	65.50		11.11	9.86	6.50			5552	4512			5.0	5.0
31		47.30	79.50	66.00		2.83	1.92	0.76			3932	3289			5.0	5.0
32		50.50	83.00	68.00		6.77	4.40	3.03			4036	3346			5.0	5.0
33		50.50	87.00	71.50		0.00	4.82	5.15			4236	3482			5.0	5.0
34		55.00	91.50	74.00		8.91	5.17	3.50			4418	3625			5.0	5.0
35		55.90	95.50	76.50		1.64	4.37	3.38			4650	3750			5.0	5.0

36	58.20	99.00	79.00	4.11	3.66	3.27	4832	3857	5.0	5.0
37	58.20	103.5	81.50	0.00	4.55	3.16	5021	4004	5.0	5.0
38	59.50	107.5	85.00	2.23	3.86	4.29	5232	4154	5.0	5.0
39	61.40	112.0	88.00	3.19	4.19	3.53	5476	4304	5.0	5.0
40	63.60	116.0	89.00	3.58	3.57	1.14	4028	3154	5.0	5.0

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

Age (days)	% Solids in Formula		Intake (ml/day)		Energy intake from formula (kcals ME/day)		Energy intake/g body mass (kcals ME/g)	
	SFZ	BZ	SFZ	BZ	SFZ	BZ	SFZ	BZ
1	13.7		56		39.2		0.061	
2	13.7		164		114.8		0.196	
3	13.7		272		190.4		0.298	
4	15.4		233		198.1		0.298	
5	15.4	7.3	252	52	214.2	22.0	0.268	0.031
6	17.3	10.4	252	120	239.4	72.4	0.266	0.101
7	17.3	14.6	252	174	239.4	147.3	0.239	0.214
8	20.3	17.7	224	235	255.4	241.5	0.250	0.346
9	20.3	24.4	222	166	253.1	233.1	0.222	0.309
10	20.3	21.4	206.5	121.5	235.4	111.9	0.193	0.145
11	20.3	21.7	196	123.5	223.4	151.5	0.175	0.197
12	20.3	21.9	196	87	223.4	110.5	0.169	0.140
13	20.3	25.6	252	145	287.3	214.6	0.208	0.266
14	20.3	29.2	196	160	223.4	270.4	0.155	0.329
15	24.3	29.2	252	190	365.4	321.1	0.230	0.377
16	24.3	21.9	194	110	281.3	153.6		0.172
17	24.3	11.0	196	128	284.2	84.3		0.093
18	24.3	17.1	196	160	284.2	264.2		0.306
19	24.3	23.1	196	157	284.2	217.3		0.246
20	24.3	23.9	196	169	284.2	241.7		0.280
21	24.3	23.9	196	185	284.2	264.6	0.156	0.295
22	24.3	23.9	294	200	426.3	286.0		0.315
23	24.3	23.9	324	199	469.8	284.6		0.293
24	24.3	23.9	294	196	426.3	280.3		0.280
25	24.3	21.1	311	130	451.0	159.5		0.159
26	24.3	18.4	311	264	451.0	290.4		0.278
27	24.3	18.4	311	280	451.0	308.0		0.273
28	24.3	18.4	354	301	513.3	331.1		0.274
29	30.9	18.4	322	325	550.6	357.5		0.279
30	30.9	18.4	290	335	495.9	368.5	0.180	0.275

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

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

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

Table 14. Polar bear cub energy intake Weeks 9-40

Weeks of age	% Solids in Formula				Intake (ml/day)				Energy intake from formula (kcals ME/day)				Energy intake/g body mass (kcals ME/g)			
	SFZ	BZ	SDM	SDF	SFZ	BZ	SDM	SDF	SFZ	BZ	SDM	SDF	SFZ	BZ	SDM	SDF
9	30.9	18.4			510	1046			872.1	1150.6				0.223		
10	30.9	18.4			510	1073			872.1	1180.5			0.137	0.180		
11	30.9	18.9			398	1192			681.3	1329.3			0.102	0.167		
12	30.9	19.6			448	1323			766.1	1500.4			0.098	0.156		
13	30.9	20.2			476	1211			814.0	1399.0				0.172		
14		21.1	26.3	26.3		1418	1882	1563		1672.5	3030.2	2517.1		0.177	0.323	0.316
15		21.6	29.9	29.9		1926	1972	1597		2306.4	3585.0	2901.1		0.160	0.352	0.358
16		24.0	30.5	30.5		1824	2334	2007		2317.8	4317.6	3712.2		0.151	0.359	0.354
17		25.5	30.5	30.5		1876	2833	2513		2476.7	5241.6	4649.3		0.129	0.356	0.370
18		25.5	30.5	30.5		1978	2279	2043		2610.6	1807.2	1619.5		0.127	0.249	0.188
19		25.5	30.5	30.5		2159	3559	2787		2850.4	6583.8	5156.3		0.134	0.283	0.241
20		25.5	30.5	30.5		2366	2792	2675		3123.7	5164.9	4948.5		0.130	0.135	0.177
21		25.5	30.5	30.5		2623	3265	3492		3462.5	5546.5	6461.0		0.130	0.110	0.236
22		24.5	30.5	30.5		2143	2875	3422		2756.9	5403.3	6330.2		0.086	0.161	0.216
23		21.9	30.5	30.5		1784	3779	3891		2151.3	6990.9	7197.6		0.056	0.168	0.222
24		21.9	30.5	30.5		1287	3965	4380		1551.6	7334.5	8103.3		0.040	0.144	0.181
25		21.9	30.5	30.5		942	4344	4017		1135.5	8036.9	7432.2		0.030	0.189	0.189
26		21.9	30.5	30.5		687	4289	3957		828.0	7933.9	7320.7		0.020	0.154	0.151
27		21.9	30.5	30.5		504	4423	4030		607.7	8182.3	7455.0		0.014	0.146	0.147
28		21.9	30.5	30.5		369	4949	4406		445.0	9155.4	8150.6		0.009	0.145	0.147
29		21.9	30.5	30.5		289	5480	4783		348.5	10138.0	8848.3			0.148	0.148
30			30.5	30.5			5552	4512			10271.5	8347.7			0.091	0.071
31			30.5	30.5			3932	3289			7274.5	6085.2			0.093	0.093
32			30.5	30.5			4036	3346			7343.8	6090.1			0.088	0.088
33			30.5	30.5			4236	3482			7539.6	6198.2			0.088	0.087
34			30.5	30.5			4418	3625			7863.8	6452.5			0.088	0.087
35			30.5	30.5			4650	3750			8277.0	6675.0			0.089	0.089

36	30.5	30.5	4832	3857	8601.2	6865.7	0.088	0.087
37	30.5	30.5	5021	4004	8938.1	7126.4	0.088	0.089
38	30.5	30.5	5232	4154	9313.2	7393.4	0.089	0.089
39	30.5	30.5	5476	4304	9746.8	7661.6	0.089	0.088
40	30.5	30.5	4028	3154	7170.3	5613.4	0.052	0.053

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

e. Weaning

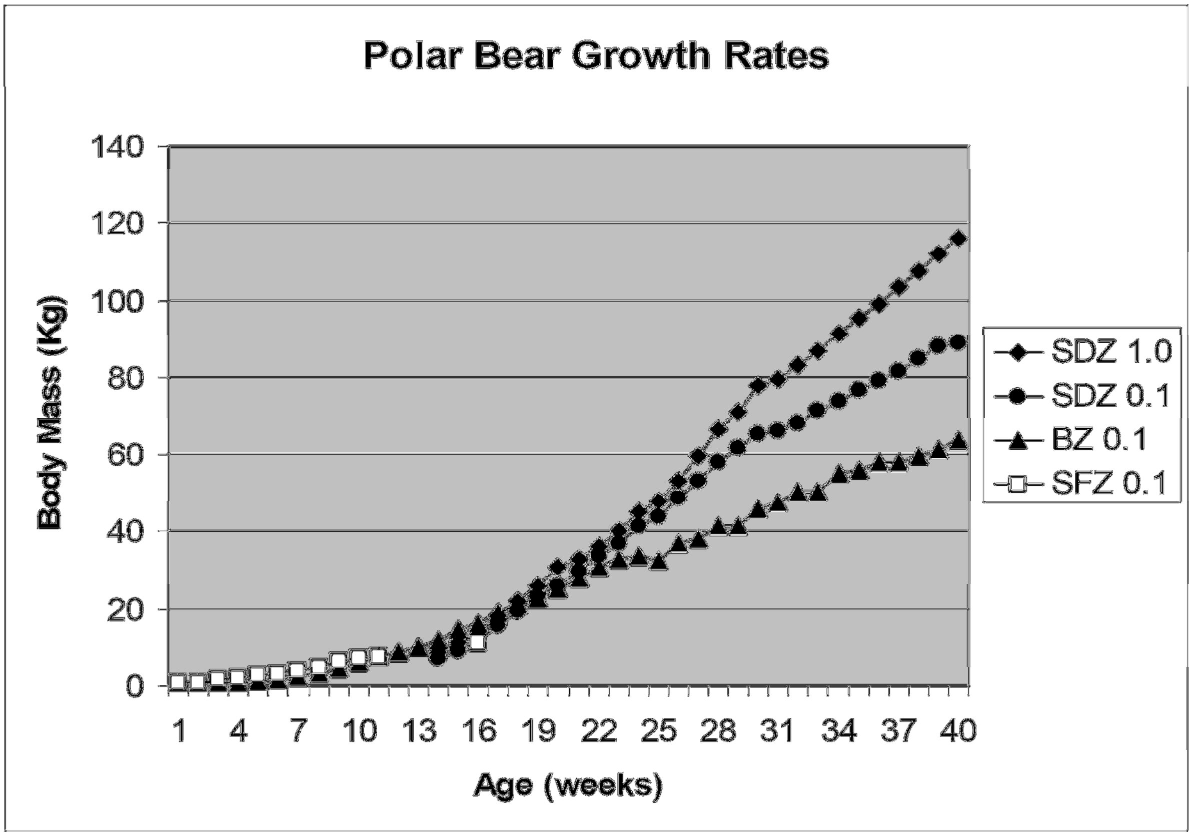
Polar bear cubs nurse for up to 2-3 years in the wild (Briggs, 2001). The age at which the contribution of nursing transitions from nutritional dependence to social bonding with the sow is unclear. Weaning in the wild involves both nutritional and behavioral processes, while captive weaning typically 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
Lacteeze - http://www.gelda.com/web_pages/pharma_products_lacteeze.html

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

Food Category			Diets - Percent of the diet as fed			
			Example 1	Example 2	Example 3	Example 4
Nutritionally complete dry diet			5	50	5	15
Nutritionally complete raw diet			44.5	30	75	32.5
Fish			30	15	15	30
Meat from Bones[1]			5	5	5	7
Whole Prey			2.5	0	0	2.5
Produce			10	0	0	10
Misc (enrichment)			3	0	0	3
Total			100	100	100	100
Nutrient	Unit	Diets - Nutrient levels on a dry matter basis.				
		Minimum Dietary Recommendations Polar Bear[a]	Example 1	Example 2	Example 3	Example 4
Protein	%	25	35.75	28.13	35.36	34.17
Fat	%	5-20	9.56	6.07	6.94	8.88
Taurine	%	0.1	0.13	0.26	0.18	0.16
Linoleic acid	%	1	1.27	1.73	1.76	1.31
Vitamin A	IU/g	5	16.02	8.22	10.1	14.44
Vitamin D_3	IU/g	1.8	2.4	2.19	2.34	2.31
Vitamin E	IU/kg	100	140.2	122.6	225	111.4
Thiamin	mg/kg	5	7.19	11.26	10.16	8.1
Riboflavin	mg/kg	4	9.04	8.34	13.26	8.11
Niacin	mg/kg	40	126.1	115.6	183.5	118.8
Pyridoxine	mg/kg	4	12.79	10.18	18.32	11.65
Folacin	mg/kg	0.5	0.57	0.92	0.85	0.62
Biotin	mg/kg	0.07	0.15	0.2	0.24	0.15
Vitamin B_{12}	mg/kg	0.02	0.04	0.04	0.06	0.03
Pantothenic acid	mg/kg	5	7.96	10.7	12.15	7.9
Choline	mg/kg	1200	1792	2070	2399	1775
Calcium	%	0.6	1.08	1.02	0.91	1.09
Phosphorus	%	0.5	0.95	0.85	0.81	0.94
Magnesium	%	0.04	0.09	0.06	0.08	0.98
Potassium	%	0.6	1.02	0.7	0.88	0.94
Sodium	%	0.2	0.33	0.24	0.28	0.31
Iron	mg/kg	80	111.8	98.79	122.1	107.1
Zinc	mg/kg	97	97.86	177.5	120.1	122.4
Copper	mg/kg	10	10.43	14.93	13.59	11.3
Manganese	mg/kg	7.5	14.2	9.44	15.72	12.01
Iodine	mg/kg	1.5	[b]	[b]	[b]	[b]
Selenium	mg/kg	0.1	0.51	0.25	0.52	0.41

b. 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.

Nutrient	Unit	Nutrient levels on a dry matter basis.

		Minimum Dietary Recommendations Polar Bear[a]	Minimum	Maximum
Protein	%	25	23	-
Fat	%	5-20	5	-
Fiber	%	-	-	4
Ash	%	-	-	11.5
Linoleic acid	%	1	1.8	-
Vitamin A	IU/g	5	5.6	-
Vitamin D_3	IU/g	1.8	2	-
Vitamin E	IU/kg	100	90	-
Thiamin	mg/kg	5	12	-
Riboflavin	mg/kg	4	7	-
Niacin	mg/kg	40	90	-
Pyridoxine	mg/kg	4	7	-
Folacin	mg/kg	0.5	1.0	-
Biotin	mg/kg	0.07	0.2	
Vitamin B_{12}	mg/kg	0.02	0.03	-
Pantothenic acid	mg/kg	5	11	-
Choline	mg/kg	1200	2000	-
Calcium	%	0.6	1.0	-
Phosphorus	%	0.5	0.8	-
Magnesium	%	0.04	0.05	-
Potassium	%	0.6	0.6	-
Sodium	%	0.2	0.2	-
Iron	mg/kg	80	90	-
Zinc	mg/kg	97	200	-
Copper	mg/kg	10	16	-
Manganese	mg/kg	7.5	8.0	-
Iodine	mg/kg	1.5	1.0	-
Selenium	mg/kg	0.1	0.13	-

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. [a]Suggested minimum polar values

complied by the polar bear nutrition working group.

Nutrient	Unit	Nutrient levels on a dry matter basis.

		Minimum Dietary Recommendations Polar Bear[a]	Minimum	Maximum
Protein	%	25	30	-
Fat	%	5	5.0	40
Fiber	%	-	-	6.7
Ash	%	-	-	8
Linoleic acid	%	1	2.0	-
Vitamin A	IU/g	5	5.0	-
Vitamin D_3	IU/g	1.8	2.0	-
Vitamin E	IU/kg	100	300	-
Thiamin	mg/kg	5	11.0	-
Riboflavin	mg/kg	4	16.0	-
Niacin	mg/kg	40	200	-
Pyridoxine	mg/kg	4	20.0	-
Folacin	mg/kg	0.5	1.0	-
Biotin		0.07	0.3	
Vitamin B_{12}	mg/kg	0.02	0.08	-
Pantothenic acid	mg/kg	5	15.0	-
Choline	mg/kg	1200	2639	-
Calcium	%	0.6	0.7	-
Phosphorus	%	0.5	0.6	-
Magnesium	%	0.04	0.07	-
Potassium	%	0.6	0.8	-
Sodium	%	0.2	0.2	-
Iron	mg/kg	80	128	-
Zinc	mg/kg	97	110	-
Copper	mg/kg	10	15.0	-
Manganese	mg/kg	7.5	20.0	-
Iodine	mg/kg	1.5	1.0	-
Selenium	mg/kg	0.1	0.5	-

d. **S**

p

e

cification for appropriate nutritionally complete meat mix - when fed according

the suggested ranges (30% minimum to 75% maximum) of the diet as fed, will result in meeting the target nutrient range. [a]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

1. Are the documents in order? A. Type and size of fish B. Size of entire shipment: number of boxes/containers C. Quantity: total quantity by weight of shipment D. Freezing method: block - IQF – shatter pack E. Pricing	YES	NO
2. Is the packaging size correct?	YES	NO
3. If required, are the boxes dated?	YES	NO
4. If required, is there a history of the catch included?	YES	NO
5. Are there any nonfood items in the shipping vehicle?	YES	NO

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? B. Are any of the boxes stained or distorted?	YES YES YES	NO NO 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).

Factor	**Acceptable**	**Inferior**	**Unacceptable**
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).

Factor	**Acceptable**	**Inferior**	**Unacceptable**

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

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

Institution	AM	PM
Milwaukee County Zoo	X	X
Baltimore Zoo	X	X
Oregon Zoo	X+	X+
North Carolina Zoo	X	2X
San Diego Zoo	X+	X+
Sea World of California, San Diego	X+	X+
Toledo Zoo	X+	X+
San Francisco Zoological Gardens	X	X
Indianapolis Zoo	X	X
Buffalo Zoo	X+	X+
Cincinnati Zoo	X	X
Louisville Zoo	X	X
Henry Vilas Zoo	X	X
Point Defiance Zoo and Aquarium	X	X+
Philadelphia Zoo	X	X

Brookfield Zoo	X	X
Lincoln Park	X	X
Saint Louis Zoo	X	X
St. Paul's Como Zoo	X	X

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

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

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.

<u>ZURICH</u>
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.

l. 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.

<u>Summary from 34 zoo</u>:

- 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.

	Meat (n=24)	**Other (n=22)**	**Fish (n=23)**
Average: all zoos	3.8 (range: 0.25 – 8.5)	3,3 (range: 0.5 – 9.4)	3,0 (range: 0.5 – 8.5)
Average: zoos with reproduct.	4.0 (range: 0.25 – 8.5)	3.1 (range: 1 – 9.4)	3.0 (range: 0.3 – 8.5)
Average: zoos without reprod.	3.5 (range: 2 – 5)	3.5 (range: 0.5 – 5)	3.3 (range 0.5 – 6)

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.

n. Summary of AZA Bear TAG survey results on consumption of protein, fat, fiber, calcium, phosphorus, vitamin A and vitamin E on a dry matter basis (DMB) from 1996-2001.

Crude Protein Consumed, % DMB, Female Polar Bears ONLY

Location	Zoo	Fall	Winter	Spring	Summer
North	Detroit	42.56			
Midwest	Lincoln Park		40.78	37.78	
Midwest	Indianapolis	38.14	37.51		
West	San Francisco		51.33		
Southeast	North Carolina		59.41		54.43
Southwest	Reid Park	37.00	33.29		
Average		40.52	44.78	37.78	54.43
Standard Deviation		3.17	9.98		
Number of Animals		5	8	1	1

Crude Protein Consumed, % DMB, Male Polar Bears ONLY

Location	Zoo	Fall	Winter	Spring	Summer
North	Detroit	36.77			
Midwest	Lincoln Park			37.77	
Midwest	Indianapolis	34.06	34.46		
Southeast	North Carolina		51.85		54.17
South	San Antonio		27.95		
Average		35.42	38.81	37.77	54.17
Standard Deviation		1.92	12.21		
Number of Animals		2	5	1	1

Crude Fiber Consumed, % DMB, Female Polar Bears ONLY

Location	Zoo	Fall	Winter	Spring	Summer

North	Detroit	5.65			
Midwest	Lincoln Park		3.05	3.28	
Midwest	Indianapolis	2.88	2.88		
West	San Francisco		1.43		
Southeast	North Carolina		1.99		2.56
Southwest	Reid Park	3.56	3.60		
Average		4.68	2.43	3.28	2.56
Standard Deviation		1.45	1.01		
Number of Animals		5	8	1	1

Crude Fiber Consumed, % DMB, Male Polar Bears ONLY					
Location	Zoo	Fall	Winter	Spring	Summer
North	Detroit	7.49			
Midwest	Lincoln Park			3.41	
Midwest	Indianapolis	2.44	2.52		
Southeast	North Carolina		2.74		2.44
South	San Antonio		3.53		
Average		4.97	3.01	3.41	2.44
Standard Deviation		5.30	0.50		
Number of Animals		2	5	1	1
Crude Fat Consumed, % DMB, Female Polar Bears ONLY					
Location	Zoo	Fall	Winter	Spring	Summer
North	Detroit	15.50			
Midwest	Lincoln Park		17.71	15.34	
Midwest	Indianapolis	23.21	21.62		
West	San Francisco		20.36		
Southeast	North Carolina		23.90		24.92
Southwest	Reid Park	16.30	14.07		
Average		17.20	19.06	15.34	24.92
Standard Deviation		3.52	4.44		
Number of Animals		5	8	1	1
Crude Fat Consumed, % DMB, Male Polar Bears ONLY					
Location	Zoo	Fall	Winter	Spring	Summer
North	Detroit	12.29			
Midwest	Lincoln Park			15.19	
Midwest	Indianapolis	35.41	31.92		

Southeast	North Carolina		21.97		23.41
South	San Antonio		11.03		
Average		23.85	19.59	15.19	23.41
Standard Deviation		16.35	9.00		
Number of Animals		2	5	1	1

Calcium Consumed, % DMB, Female Polar Bears ONLY					
Location	Zoo	Fall	Winter	Spring	Summer
Midwest	Lincoln Park		2.67	3.06	
Midwest	Indianapolis	2.48	2.60		
West	San Francisco		1.03		
Southeast	North Carolina		2.49		2.17
Southwest	Reid Park	2.89	2.22		
Average		2.69	1.91	3.06	2.17
Standard Deviation		0.29	0.80		
Number of Animals		2	8	1	1
Calcium Consumed, % DMB, Male Polar Bears ONLY					
Location	Zoo	Fall	Winter	Spring	Summer
Midwest	Lincoln Park			3.07	
Midwest	Indianapolis	2.03	2.21		
Southeast	North Carolina		2.1		2.27
South	San Antonio		2.15		
Average		2.03	2.14	3.07	2.27
Standard Deviation			0.27		
Number of Animals		1	5	1	1
Phosphorus Consumed, % DMB, Female Polar Bears ONLY					
Location	Zoo	Fall	Winter	Spring	Summer
Midwest	Lincoln Park		1.42	1.56	
Midwest	Indianapolis	1.64	1.67		

West	San Francisco		1.21		
Southeast	North Carolina		1.73		1.64
Southwest	Reid Park	1.44	1.26		
Average		1.54	1.37	1.56	1.64
Standard Deviation		0.14	0.25		
Number of Animals		2	8	1	1
Phosphorus Consumed, % DMB, Male Polar Bears ONLY					
Location	Zoo	Fall	Winter	Spring	Summer
Midwest	Lincoln Park			1.54	
Midwest	Indianapolis	1.42	1.48		
Southeast	North Carolina		1.46		1.65
South	San Antonio		1.47		
Average		1.42	1.47	1.54	1.65
Standard Deviation			0.16		
Number of Animals		1	5	1	1

Vitamin A Consumed, IU/g DMB, Female Polar Bears ONLY					
Location	Zoo	Fall	Winter	Spring	Summer
Midwest	Lincoln Park		36.00	35.35	
Midwest	Indianapolis	15.65	16.12		
West	San Francisco		45.45		
Southeast	North Carolina		25.66		19.97
Southwest	Reid Park	80.87	49.33		
Average		48.26	39.10	35.35	19.97
Standard Deviation		46.12	16.79		
Number of Animals		2	8	1	1
Vitamin A Consumed, IU/g DMB, Male Polar Bears ONLY					
Location	Zoo	Fall	Winter	Spring	Summer
Midwest	Lincoln Park			32.23	
Midwest	Indianapolis	13.77	14.21		
Southeast	North Carolina		20.97		22.72
South	San Antonio		21.21		
Average		13.77	19.71	32.23	22.72
Standard Deviation			3.55		
Number of Animals		1	5	1	1

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

Location	Zoo	Fall	Winter	Spring	Summer
Midwest	Lincoln Park		1.61	2.36	
Midwest	Indianapolis	5.63	5.95		
West	San Francisco		1.48		
Southeast	North Carolina		3.02		2.24
Southwest	Reid Park	2.20	2.17		
Average		3.92	2.42	2.36	2.24
Standard Deviation		2.43	1.58		
Number of Animals		2	8	1	1
Vitamin D3 Consumed, IU/g DMB, Male Polar Bears ONLY					
Location	Zoo	Fall	Winter	Spring	Summer
Midwest	Lincoln Park			2.44	
Midwest	Indianapolis	4.25	4.40		
Southeast	North Carolina		2.38		2.60
South	San Antonio		3.17		
Average		4.25	3.10	2.44	2.60
Standard Deviation			0.90		
Number of Animals		1	5	1	1

Vitamin E Consumed, IU/kg DMB, Female Polar Bears ONLY					
Location	Zoo	Fall	Winter	Spring	Summer
Midwest	Lincoln Park		166.20	165.60	
Midwest	Indianapolis	410.10	380.70		
West	San Francisco		268.20		
Southeast	North Carolina		330.20		401.90
Southwest	Reid Park	212.60	263.20		
Average		311.35	276.01	165.60	401.90
Standard Deviation		139.65	90.60		
Number of Animals		2	8	1	1
Vitamin E Consumed, IU/kg DMB, Male Polar Bears ONLY					
Location	Zoo	Fall	Winter	Spring	Summer
Midwest	Lincoln Park			166.30	
Midwest	Indianapolis	357.50	313.40		
Southeast	North Carolina		275.9		373.40
South	San Antonio		136.1		
Average		357.50	227.48	166.30	373.40
Standard Deviation			88.99		

Number of Animals	1	5	1	1

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

POLAR BEARS (Holly Reed, D.V.M. Polar Bear Veterinary Advisor)

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 up stream) 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. helminthoeca 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 Chloramphenacol 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 ○ 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.

Burrows, G.E., and Tyrl, R.J. 2001. Toxic Plants of North America. Iowa State University Press. Ames, IA.

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
http://cbif.gc.ca/pls.pp/poison?p_x=px

10. LITERATURE CITED

Association of American Feed Control Officials (AAFCO). 2004. Dog and Cat Nutrient Profiles. Published by The Association of American Feed Control Officials. Oxford, IN. Pp:128-143.

Atkinson, S.N., R.A. Nelson, and M.A. Ramsey. 1996. Changes in the body composition of fasting polar bears (*Ursus maritimus*): the effect of relative fatness on protein conservation. Physiol. Zool. 69(2):304-316.

Atkinson S.N. and M.A. Ramsey. 1995. The effects of prolonged fasting of the body composition and reproductive success of female polar bears (Ursus maritimus). Functional Ecology. Vol 9:559-567.

Ben Shaul, D.M.1962. Animal milk analyses and hand-rearing techniques. Int. Zoo Yrbk. 4:333-342.

Bernard J.B., and M.E. Allen. 1997. Feeding Captive Piscivorous Animals: Nutritional Aspects of Fish as Food. Nutrition Advisory Group Handbook Fact Sheet 005. www.NAGonline.net

Brannon, R.D. 1985. Serum chemistry values of central and central and northern Alaska grizzly bear. J. W. Man. 49:893-900.

Best, R.B. 1985. Digestibility of ringed seals by the polar bear. Can. J. Zool. V:63:10331036.

Briggs, M.B. 2001. Polar Bears. In: CRC Handbook of Marine Mammal Medicine, 2nd ed. Dierauf, L.A. and F.M.D. Gulland, eds. CRC Press, NewYork. Pp990-992.

Case, L.P., D.P. Carey, D.A. Hirakawa, and L. Daristotle. 2000. Canine and feline nutrition a resource for companion animal professionals. Mosby, Inc. St. Louis, MO.

Case, L.P. 1999. The dog it's behavior, nutrition, and health. Iowa State University Press, Ames, IA.

Cattet, M. 1990. Predicting nutritional condition in black bears and polar bars on the basis of morphological and physiological measurements. Can. J. Zool. V. 68:32-39.

Clemens.E.T., 1996. IAMS: Dietary fiber and colonic Morphology. Recent advances in canine and feline nutrition research. Proc. of Intl. Nutrient Symposium. Eds: D.P. Carey, S.A. Norton, S.M. Bolser. Orange Frazer Press, Willington, OH. pp25-32.

Colby, R.H., C.A. Mattacks, and C.M. Pond. 1993. The gross anatomy, cellular structure, and fatty acid composition of adipose tissue in captive polar bears (*Urus maritimus*). Zoo Biol. 12:267-275.

Crissey, S.D., K.A. Ange, K.A. Slifka, W. Sadler, S. Kahn, and A.M. Ward. 2004. Serum lipid concentrations in six canid and four ursid species in four zoos. J. Zoo and Wild. Manag. 32(1):34-39.

Crissey, S.D., K.A. Ange, K.A. Slifka, P. Bowen, M. Stacewicz-Sapuntzakis, C. Langman, W. Sadler, and A.M. Ward. 2001. Serum concentrations of vitamin D metabolites, vitamins A and E, and carotenoids in six canid and four ursid species at four zoos. Comp. Biochem. Phys. Part A 128:155-165.

Crissey, S.D., K.A. Slifka, P. Shumway, and S.B. Spencer. 2001. Handling Frozen/Thawed Meat and Prey Items Fed to Captive Exotic Animals: A Manual of Standard Operating Procedures. U.S. Department of Agriculture, Agricultural Research Service, National Agriculture Library. Animal and Plant Health Inspection Service, Beltsville, MD. Pp:1-23.

Crissey, S. D. 1998. Handling Fish Fed to Fish-Eating Animals: A Manual of Standard Operating Procedures. United States Department of Agriculture, Agriculture Research Service, National Agricultural Library, Animal and Plant Health Inspection Service, Beltsville, MD. http://www.nal.usda.gov/awic/pubs/fishhndl.htm

Crissey, S.D., M.E. Allen, and D.J. Baer. 1987. Food handling and commissary procedures. *In* T.P. Meehan and M.E. Allen, eds., Proceedings of the 6th and 7th Dr. Scholl Conferences on the Nutrition of Captive Wild Animals, Chicago, December 1987, pp. 119-123. Lincoln Park Zoo, Chicago.

Derocher, A.E., O. Wiig, and Magnus Andersen. 2002. Diet composition of polar bears in Svalbard and the western Barents Sea. Polar Biol. 25:448-452.

Derocher, A.E., O. Wiig, and G. Bangjord. 2000. Predation of Svalbard reindeer by polar bears. Polar Biol. 23:675-678.

Derocher, A.E., D. Andriashek, and J.P.Y. Arnould. 1993. Aspects of milk composition and lactation in polar bears. Can. J. Zool. 71:561-567.

Farley, S.D., and Robbins, C.T. 1994. Development of two methods to estimate body composition of bears. Canadian Journal of Zoology 72:220-226.

Felicetti, LA, CT Robbins, and LA Shipley. 2003. Dietary protein content alters energy expenditure and composition of the mass gain in grizzly bears (*Ursus arctos horribilis*). Physiological and Biochemical Zoology 76:256-261.

Foster, J. W. 1981. Dermatitis in polar bears-A nutritional approach to therapy. Woodland Park Zoo, Seattle WA, unpublished manuscript.

Frazier, W.C., and D.C. Westhoff. 1988. Food microbiology, 4th ed. McGraw-Hill, New York.

Geraci, J.R. 1978. Nutrition and nutritional disorders. *In* M.E. Fowler., ed., Zoo and Wild Animal Medicine, pp. 568. W.B. Saunders, Philadelphia

Griffin, M.E. 2004. Personal Communication.

Hedberg, G. 2005. Personal Communication.

Hess, J.K. 1971. Hand-rearing polar bear cubs (*Thalarctos maritimus*) at St Paul Zoo. Int. Zoo Yrbk. 11:102-107.

Higashi, N. and H. Senoo. 2003. Distribution of vitamin A-Storing Lipid Droplets in Hepatic Stellate Cells in Liver Lobules- A Comparative Study. The Anatomical Record. Part A 271A:240-248.

Hilderbrand, G.V., Farley, S.D., and Robbins, C.T. 1998. Predicting body condition of bears via two field methods. Journal of Wildlife Management 62:406-409

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

Hollick, M.F. 1999. Vitamin D: Physiology, Molecular Biology, and Clinical Applications. Humana Press, Totowa, New Jersey.

Hoppner,K., McLaughlin,J.M., Shah,B.G., Thompson,J.N., Beare-Rogers,J., EllestadSayed,J., Schaefer,O. 1978. Nutrient Levels of some foods of Eskimos fromArtic Bay,N.W.T., Canada. Journal of the American Dietetic Association, Vol 73, September.

Jenness, R., A.W. Erickson, and J.J. Craighead. 1972. Some comparative aspects of milk from four species of bears. J. Mammal. 53:34-47.

Kenny, D.E., T.M. O'hara, T.C. Chen, Z. Lu, X. Tian, M.F. Holick. 2004. Vitamin D content in Alaskan artic zooplankton, fishes, and marine mammals. Zoo Biology, 23:3343.

Kenny, D.E., N.A. Irlbeck, and J.L. Eller. 1999. Rickets in two hand-reared polar bear (*Ursus maritimus*) cubs. J. Zoo Wild. Med. 30(1):132-140.

Kenney, D.E., N.A. Irlbeck, T.C. Chen, Z. Lu, and M.F. Holick. 1998. Determination of vitamins D, A, and E in sera and vitamin D in milk from captive and free-ranging polar bears (*Urus maritimus*), and 7-dehydrocholestrol levels in skin from captive polar bears. Zoo Bio. 17:285-293.

Knudson, B. 1978. Time budgets of polar bears (*Urus maritimus*) on North Twin Island, James Bay, during summer. Can J. Zool. 56:1627-1628.

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

Leighton FA, Cattet M, Norstrom R, Trudeau S. 1988. A cellular basis for high levels of vitamin A in livers of polar bears (*Ursus martitimus*): the Ito cell. Can. J. Zool. 66:480482.

Mazzaro, L., J. Lawrence, A. Tuttle, J. Goodman, J. Wyatt, and E. Kadyszewski. 2003. Plasma electrolyte concentrations for African penguins (*spheniscus demersus*) and their relationship to habitat type and salt supplementation. Proc. of the NAG 5th conference on Zoo and Wildlife Nutrition. Pp:111.

National Research Council. 2006. Nutrient Requirements of Cats and Dogs. National Academy Press, Washington, D.C. In Press.

Nelson, R. 1983. Feeding strategies and metabolic adjustments of the polar bears. Proc. of the 3rd Dr. Scholl Conference. Lincoln Park Zoo, Chicago, IL. pp93-96

Oftedal, O.T., and D.J. Boness. 1983. Considerations in the use of fish as food. *In* T.P. Meehan and M.E. Allen, eds., Proceedings of the Third Annual Dr. Scholl Nutrition Conference, Chicago, December 1983, pp. 149-161. Lincoln Park Zoo, Chicago.

Robbins, C. T. 1993. Wildlife Feeding and Nutrition. Academic Press, Inc. San Diego, CA.

Russell, R.H. 1975. The Food habits of Polar bears of James Bay and Southwest Hudson Bay in summer and autumn. Artic. 28:117-128.

Schweigert, F.J., O.A. Ryder, W.A. Rambeck, and H. Zucker. 1990. The majority of vitamin A is transported as retinyl esters in the blood of most carnivores. Comp Biochem Phys. Vol 4:573-578.

Shrestha, S.P., D.E. Ullrey, J.B. Bernard, C. Wemmer, B.E. Kraemer. 1998. Plasma vitamin E and other analyte levels in Nepalese Camp elephants (*Elephas maximus*). J.Zoo and Wild. Med. 29(3):269-278

Smith,T.G., Sjare,B. 1990. Predation of Belugas and Narwhals by Polar bears in Nearshore areas of the Canadian high Artic. Artic. Vol 43, No 2, June, pp 99-102.

Stoskopf, M.K. 1986. Feeding piscivorous birds, a review. Annual Proceedings of the American Association of Zoo Veterinarians, pp. 69-87.

Stephens, C.E. and I.D. Hume. 1995.Comparative Physiology of the Vertebrate Digestive System. Second Ed. Cambridge University Press. New York, NY.

Stirling,I., and Archibald,W.R., 1977. Aspects of predation of seals by polar bears. J.Fish.Res.Board Can, Vol 34,pp1126-1129.

Stirling,I., 1974. Midsummer observations on the behavior of wild polar bears (Ursus maritimus). Can.J.Zool, Vol 52,pp1191-1197.

United States Department of Agriculture [USDA]. 1999. Title 9 Code of Federal Regulations, Animals and Animal Products, Part 3--Standards, Subpart E, §3.105 & §3.107, Animal and Plant Health Inspection Service, Washington, DC.

Urashima,T., T. Yamashita, T, Nakarama, I. Arai, T. Saito, A.E. Derocher, O. Wiig. 2000. Chemical Characterization of milk oligosaccharides of the polar bear Ursus maritimus. Biochemica et Biophysica acta 1475,pp395-408.

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.

West,G.C., Burns,J.J., Modafferi,M. 1979. Fatty acid composition of blubber from the four species of Bering Sea phocid seals. Can.J. Zool. Vol 57,pp189-195.

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