ASSOCIATION OF ZOOS & AQUARIUMS

POLAR BEAR
(*Ursus maritimus*)
CARE MANUAL

CREATED BY THE
AZA Polar Bear Species Survival Plan®
IN ASSOCIATION WITH THE
AZA Bear Taxonomic Advisory Group

Polar Bear (*Ursus maritimus*) Care Manual

Published by the Association of Zoos and Aquariums in association with the AZA Animal Welfare Committee

Formal Citation:

AZA Bear TAG 2009. Polar Bear (*Ursus maritimus*) Care Manual. Association of Zoos and Aquariums, Silver Spring, MD.

Original Completion Date:

16 December 2009

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This nutrition chapter is an excerpt from the complete Animal Care Manual available at the

Association of Zoos and Aquariums (AZA)'s website:

http://www.aza.org/animal-care-manuals/

Further information about diets and the nutrition of this and other species can be found at the

AZA's Nutrition Advisory Group (NAG)'s website:

http://nagonline.net

Chapter 5. Nutrition

5.1 Nutritional Requirements

> **AZA Accreditation Standard**
>
> **(2.6.2)** A formal nutrition program is recommended to meet the behavioral and nutritional needs of all species and specimens within the collection.

A formal nutrition program is recommended to meet the behavioral and nutritional needs of polar bears. Diets should be developed using the recommendations of nutritionists, the AZA Nutrition Scientific Advisory Group's (SAG) guidelines (www.nagonline.net/feeding_guidelines.htm), veterinarians as well as the AZA Bear TAG and Polar Bear SSP. Diet formulation should address the polar bear's nutritional needs, feeding ecology, as well as individual and natural histories, to ensure that species-specific feeding patterns and behaviors are stimulated (AZA Accreditation Standard 2.6.2).

Polar bears are the most carnivorous of the Ursidae family, and prey primarily on ringed seals in the wild (Stirling & Archibald, 1977; Best, 1985; Derocher, et al. 2000). Other seals, whales, walrus, reindeer, sea birds, carrion, and vegetation may be consumed as well (Derocher et al., 2000; Derocher, et. al, 2002; Knudson, 1978; Russell, 1975; Smith and Sjare, 1990). Research about the nutritional needs of polar bears is limited and the formulation of dietary recommendations is based on the known diets consumed by healthy bears in AZA-accredited zoos and aquariums as well as those sucessfully used with related wild and domestic animals including domestic cats and dogs (NRC, 2006; AAFCO, 2004).

Cats are obligate carnivores since there are nutrients they need to obtain from their diet as their bodies can't produce them. Dogs are not obligate carnivores as they have the ability to snyhesize these nutrients thus they can survive on a more varied diet. Bears range in their feeding types. At this point data do not exist for polar bears indicating they are obligate carnivore or strictly omnivore. Polar bears in the wild are primarily carnivorous, but will occasionally consume plant matter (Russell 1975; Knudson 1978). Polar bears in zoos and aquariums also will readily consume plant matter. Consequently, a range of nutrient levels encompassing both feeding strategies (carnivorous and omnivorous) is appropriate for the formulation of polar bear diets in zoos and aquariums. The table below (Table 4) provides the cat and dog nutrient profile minimums for all stages compared to suggested dietary recommendations for polar bears on a dry matter basis.

Table 4: Cat and dog nutrient profile minimums for all stages compared to suggested dietary recommendations for polar bears on a dry matter basis[a]

Nutrient	Unit	Minimum nutrient profile **bold = required 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

[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; The nutrient were developed by the polar bear nutrition working group.

The stomach of the Ursidae is simple, a cecum is absent, and there is no obvious external differentiation between the small and large intestine (Stephens & Hume, 1995). Similar to other carnivore species, polar bears efficiently digest protein and fat (Best, 1985). Their simple digestive tract is well suited for their carnivorous diet. Many polar bears in the wild predominantly consume the blubber of seals, or the whole seal if it is small (Stirling & Archibald, 1977; Derocher et al., 2000). The use of fat to meet energy needs conserves body protein catabolism and its resulting urea formation/urine output. Best (1985) estimated the metabolizable energy requirement for free-ranging polar bears to be 140-182kcal/$kg^{0.75}$, and reported that bears in zoo and aquarium conditions consumed 110 kcal ME/$kg^{0.75}$ (on a DE basis, 115 kcals DE/$kg^{0.75}$).

Vitamin Supplementation: The very high serum levels of fat-soluble vitamins in wild polar bears have led many scientists to hypothesize that diets in zoos and aquariums should be heavily supplemented with vitamins A, D, and E, however, no consistent health changes have been observed with these supplements. While serum levels for all of these vitamins are of interest and should 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.

Vitamin A: There is speculation that lower levels of vitamin A in the livers of polar bears in zoos and aquariums could be a factor in mortality, low reproductive rates, and coat problems. Therefore, many institutions have supplemented polar bear diets with vitamin A. Higashi & 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. This suggests that polar bears have the capacity to store large amounts of vitamin A (Leighton et al., 1988; Higashi & Senoo, 2003). 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 levels of 8.91-15.65 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.

Vitamin E and thiamin: Due to the presence of fish in many polar bear diets, some institutions supplement polar bear 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 fish that has been stored frozen (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 non-fish food items may be providing the needed nutrients. All diets should be carefully analyzed to determine if additional supplementation of vitamin E and thiamin are necessary. However, a safe approach would be always to supplement the fish portion of the diet (30mg thiamin and 100 IU vitamin E per kg fish offered), regardless of the inclusion rate of fish. This would ensure a balanced diet even if/when the proportion of fish in the diet fluctuates.

Vitamin D and calcium: Due to a small number of reported bone fractures in polar bears housed in zoos and aquariums, there is speculation that there is a need for vitamin D and calcium supplementation. However, the data presented are on a small percentage of bears and do not appear to give any indication of compromised bone density (Lintzenich et al., 2006). Providing supplementation in excess of suggested guidelines (Table 4) is not warranted for any life stage, including pregnant or nursing females.

Factors Affecting Nutritional Needs: Structural growth of female polar bears is completed by five years of age, but body mass in adults fluctuates depending on season and reproductive status (Atkinson & Ramsey, 1995). Polar bears in the wild are unusual among large mammals for their ability to tolerate extreme body weight fluctuations between periods of hyperphagia (gorging) and those of relative food deprivation. In the wild, periods of hyperphagia may occur in spring and summer, or in autumn depending on geographic area, and periods of negative foraging may occur in late winter/early spring, or late summer, depending upon the geographic area (S. Amstrup, personal communication, 2006). In zoos and aquariums, polar bears typically eat less in the spring and summer months and more in the fall and winter months, and institutions should adjust diets as needed (Lintzenich et al., 2006). Seasonal weight targets may be desirable, based on the body size of individual bears, and on the information on seasonal hyperphagia.

In the wild, the meat and the skin or the whole seal carcass (rather than blubber alone) is more often consumed by pregnant females, females with cubs, and sub-adults. During these life stages, protein requirements are increased, and more extensive carcass consumption may be the method for meeting these increased protein needs (Atkinson & Ramsey, 1995; Atkinson et al., 1996). With the exception of the cubbing period when the female's appetite decreases, and the lactation period when caloric requirements increase, reproductive status generally has little influence on dietary preferences. The motivation of male bears to eat may be reduced during the breeding season.

Additional Information: Complete nutritional information on polar bear diets, and on the handling, processing, storing, and presentation of these diets can be found in the Polar Bears International Nutrition guidelines (Lintzenich et al., 2006). This resource provides information that can be used as the foundation of an effective nutrition program specific to polar bears, but the precise nature of any nutrition program will need to be tailored to the staff and facilities available at each zoo and aquarium. Extracts from the Lintzenich et al. (2006) document are presented in this manual, and the complete document can be accessed from the Polar Bears International website:
www.polarbearsinternational.org/rsrc/pbnutritionguidelines

5.2 Diets

The formulation, preparation, and delivery of all polar bear diets must be of a quality and quantity suitable to meet the animals' psychological and behavioral needs (AZA Accreditation Standard 2.6.3). Food should be purchased from reliable, sustainable, and well-managed sources, and nutritional analyses of the food should be regularly tested and recorded.

AZA Accreditation Standard

(2.6.3) Animal diets must be of a quality and quantity suitable for each animal's nutritional and psychological needs. Diet formulations and records of analysis of appropriate feed items should be maintained and may be examined by the Visiting Committee. Animal food, especially seafood products, should be purchased from reliable sources that are sustainable and/or well managed.

A balanced diet developed for polar bears in zoos and aquariums could include a combination of nutritionally complete items (dry, raw, and/or gel), saltwater fish, bones, whole prey, produce, and food presented in enrichment devices. When fed in combination, these foods should result in nutrient levels that meet the minimum dietary recommendations (see section 5.1). In a captive study spanning institutions and seasons from 1996 to 2001 on a dry matter basis, males (average body mass 432kg/952.4 lb) consumed 0.5-0.9% of body mass and females (average body mass 227kg/500.45 lb) consumed 0.8-1.1% body mass. There may be seasonal fluctuation in food intake due to changes in the bears' activity levels. For all food items offered, especially raw meat and fish products, careful consideration should be given to temperature and environmental conditions with regard to spoilage and bacterial overgrowth that may cause illness (see Appendix F).

Food Category Suggestions: Table 5 provides suggested proportions of various food categories for polar bear diets that would meet the nutritional needs of the polar bears (see Chapter 5, section 5.1 for more information) throughout the year (Lintzenich et, al, 2006). Food quantities and subsequently caloric energy offered should be regulated based on weight trends, visual assessment of body condition and weight behavior. A study at an AZA Accredited Institution indicated dramatic seasonal weight changes in this species can be modulated through active management of the diet. For more information on modulating calories offered to promote appropriate body condition across seasons see data provided in Lintzenich et al. 2006.

Table 5: Food categories and suggested ranges with flexibility for seasonal changes (adapted from Lintzenich, et al. 2006)

Ingredients	As fed % of the diet[1] Maintenance/Growth/Lactation	
	Minimum	Maximum
Dry Nutritionally Complete Food (see Appendix G)	5	50
Raw Meat Mix Nutritionally Complete (see Appendix G)	30	75
Marine Products – saltwater fish	15	30
Produce	0	10
Meat from Shank Bone[2]	5	7
Whole Prey[3]	0	2.5
Misc.[4]	0	3

[1] Diets outside these ranges could be fed if nutrient content of ingredients when consumed as offered meet target nutrient ranges.
[2] Meat from a shank bone is 50% of the total bone weight (i.e., if a bones weighs 454 g then 227 g is meat).
[3] Whole prey is large rats or rabbit.
[4] Miscellaneous may include items for behavioral enrichment (BE).

Sample Diets: Two examples of polar bear diets are provided in Table 6 to illustrate the proportion of food categories offered as part of an overall balanced diet.

Table 6: Food categories and quantities of sample diet as fed (adapted from Lintzenich et al. 2006)

Ingredient	Sample Diet 1, %	Sample Diet 2, %
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 7 provides nutritional analyses of these diets and compares them to the minimum dietary recommendations for polar bears.

Table 7 Nutrient analysis of sample diets on a dry matter basis (adapted from Lintzenich et al. 2006)

Nutrient	Unit	Levels on a Dry Matter Basis		
		Minimum Dietary Recommendations Polar Bear[a]	Sample Diet 1[b]	Sample Diet 2[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.

Feeding schedule: In zoos and aquariums, polar bears are traditionally fed 1-2 times daily, often in the early morning and later afternoon to facilitate shifting or other management needs, but the specific feeding schedule is up to the discretion of the facility. It is strongly recommended that a regular feeding schedule for polar bears be supplemented by irregularly timed feeding opportunities, in novel locations within the exhibits, utilizing foods that are not normally provided (PBPA, 2002), in order to meet the behavioral needs of the bears. Some facilities have found that scatter feeding or feeding smaller amounts more often decreases stereotypic behavior. Many facilities feed the morning diet as enrichment "scatter feed" throughout the public exhibit. The caloric content of significant amounts of enrichment

foods, skins, etc., should be factored into the overall diet, as polar bears can develop weight problems if overfed (Lintzenich, et al. 2006).

Food variability and presentation: A study examining food consumption habits by island and mainland polar bears in the wild near Manitoba, Canada, found five primary food items consumed by the bears: birds, mammals, marine algae, grasses, and berries (Russell, 1975). Variation of *ex situ* offerings of food type, presentation styles, distribution locations, and provision timing could be considered when planning polar bear diet regimes. Offering a variety of food items, including high- and low-fat fishes, helps to ensure a complementary nutrient profile of the diet. Geraci (1978) emphasized the need to feed more than one food type in order to help ensure a balanced diet in marine mammals. This same concept could be applied to polar bears. Uncertainties in the future availability of fish stocks, and seasonal variation in the availability of certain fish, are issues that should be considered. It is possible for an animal to become imprinted on a specific food item, and if that item becomes unobtainable, it may be very difficult to coax the animal to eat a new species/item.

Carnivore-style feeding containers (flip dishes, feeding tubes) are appropriate for polar bears when food is not hidden or placed within the habitat. Polar bears can be separated into individual habitat areas for feeding in order to prevent competition as well as to allow accurate measurement of food consumption. Multiple enrichment feedings may be added to the habitat, usually without risk of competition. In general, the manner of presentation of the prescribed diet should be varied for behavioral enrichment purposes (e.g., scattered, chopped, whole, frozen in blocks, presented in feeder balls or barrels, training sessions). *In situ* polar bears with cubs can spend 35-50% of their activity budget hunting (Stirling, 1998). In order to provide opportunities to exhibit species-appropriate behaviors, or otherwise enable animals to work for food, a number of enrichment foods and items can be incorporated into/onto outdoor or indoor habitat areas. It is recommended that polar bears be offered edible items on an ongoing but random schedule in order to combat stereotypic behaviors and avoid habituation to a routine schedule. Supplemental enrichment foods (e.g., raisins, peanut butter, honey, etc.) should not exceed 3% by weight of the total diet offered (Lintzenich, et al. 2006) to ensure a balanced diet and should go through an institutional approval processes, including review by nutritionists and veterinarians. All new diet items should be monitored closely when first provided to the bears. The following items may be considered suitable enrichment foods or objects the food can be incorporated with for polar bears. This is by no means a complete list, and many other options and ideas can be used and should be considered (see also Chapter 8, section 8.2 for more information on enrichment).

- Whole chickens
- Fish
- Soft substrate pit (may become a defecation site)
- Telephone book
- Bird feathers
- Ice blocks containing food
- Logs/stumps
- Branches/wood chips from primate or small mammal exhibits
- Rope pulls
- Pine cones
- Browse
- Peanut butter, jams & jellies, honey
- Hard-boiled eggs
- Straw/hay from ungulate exhibits
- Christmas trees
- Corn stalks
- Knuckle bones
- Gelatin made with blood, Jell-O
- Skins, feet, heads from pigs, deer, domestic stock
- Boomer ball
- Cardboard box
- PVC tubes (smaller than head size)
- Raccoon, deer or elk urine - commercially purchased
- Snow
- Melons, gourds, pumpkins
- Spices & herbs: Russian sage, mint, cumin, nutmeg, catnip, cloves, basil, oregano, rosemary, rose hips/petals, allspice, cinnamon

The food type, presentation, and order of offering may have implications for dental health in polar bears and each factor should be carefully considered to promote the removal of organic buildup that can contribute to dental health issues. The AZA Bear TAG recommends that food items that are soft, or that could become soft, should be fed first and items such as bones, fish, or those with hair/skin should be offered last to help to remove soft and sticky foods from the teeth. The suggested feeding order for polar bears is 1) ground meat product or slab meat, 2) dry diet, 3) fish and vegetables and, 4) bones and chew items (hide, carcass) such as biscuits which should be fed dry and attempts should be made to prevent the bears from wetting them. Bears may need to be offered fresh and pliable bones, rawhides, ox tails, and hides more than once a week if additional tooth-cleansing assistance is needed. Synthetic hard bones, ice blocks, and hard frozen food items may contribute to tooth damage, and their use should be monitored.

Carcass feeding: Whole carcasses contribute to the overall diet of bears in the wild, and may be especially important to sub-adults and orphaned cubs (Stirling, 1974). *Ex situ* supplementation of whole carcasses can promote a wide range of feeding and foraging behaviors, however, no official standards of care describe procedures for the provisioning of animal carcasses to polar bears. The AZA Nutrition SAG recognizes the feeding of animal carcasses as a practice desired by some AZA institutions to stimulate activity and normal feeding behaviors. The AZA Nutrition SAG cautions institutions that choose to carcass-feed about numerous hazards (pathogenic and parasitic) that exist for collection carnivores (e.g., Harrison, et al. 2006). Precautions are necessary to ensure the carcass is wholesome and all institutions responsible for feeding *ex situ* populations of carnivores should be aware of and follow USDA policy # 25 (USDA, 1998). Although this policy was written specifically for large felids, the AZA Nutrition SAG recommends it be applied to polar bears and that caution be employed to ensure wholesome feeding practices including the acquisition of fresh carcasses with appropriate handling to ensure rapid cool down and minimal bacterial contamination. According to the AZA Nutrition SAG's statement on carcass feeding, if the carcass is not that of a neonate collected at birth, the removal of head, hide, and internal organs is recommended. The authors of this chapter would consider the removal of hide and/or feeding of hides may not be an issue in polar bears. Finally, and most importantly, unless the carcass is that of a neonate collected at birth and fed fresh or is from a USDA inspected facility, the institution must freeze the carcasses solid and properly defrost it prior to offering to an animal to minimize potential parasite exposure. The AZA Nutrition SAG only condones carcass feeding as part of a feeding program that ensures the diet of the animal is nutritionally balanced and wholesome and these institutions acquire the carcasses from USDA inspected facilities. For issues surrounding the practice of feeding whole fish to polar bears (including the use of live fish) see Appendix F. The feeding of road kill should be done only under very close veterinary consultation or supervision.

AZA Accreditation Standard

(2.6.1) Animal food preparations must meet all local, state/provincial, and federal regulations.

Food Selection, Storing, Handling, and Processing: Food preparation must be performed in accordance with all relevant federal, state, or local regulations (AZA Accreditation Standard 2.6.1). Meat and seafood processed on site must be processed following all USDA standards and the appropriate hazard analysis and critical control points (HACCP) food safety protocols for the diet ingredients, diet preparation, and diet administration should be established for the taxa or species specified. Diet preparation staff should remain current on food recalls, updates, and regulations per USDA/FDA. Remove food within a maximum of 24 hours of being offered unless state or federal regulations specify otherwise and dispose of per USDA guidelines. For a complete description of the proper handling and processing of meat and fish products see Crissey (1998) and Crissey, et al. (2001a) and meat processed on site must be follow all USDA standards. Storage and handling of food enrichment items should follow the same standards as those for other diet ingredients. The inspection of fish fed to polar bears is extremely important to ensure they are of the highest quality. While no single test can determine fish quality (Lintzenich, et al. 2006), Table 8 (adapted from Lintzenich, et al. 2006) provides factors that should be carefully evaluated (Oftedal & Boness, 1983; Stoskopf, 1986; Frazier & Westhoff, 1988). Similar criteria can also be used when assessing other types of meat provided to bears (see Lintzenich, et al. 2006).

Table 8: Criteria used to assess the suitability of raw fish fed to polar bears (adapted from Lintzenich et al. 2006)

Factor	Acceptable	Inferior	Unacceptable
General appearance	Shine or luster to skin; no breaks in skin, 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

Factor	Acceptable	Inferior	Unacceptable
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

Browse: *In situ* polar bears have been observed ingesting vegetation (Russell, 1975; Knudson, 1978). The use of browse for enrichment purposes is common with polar bears (willow is particularly successful but other species will also be effective) who will manipulate and ingest parts of some browse species provided to them. Zoos and aquariums should have a process in place to evaluate which species of browse are selected and how they are evaluated for safety. The responsibility for approval of plants and oversight of the program should be assigned to at least one qualified individual within each institution (AZA Accreditation Standard 2.6.4).

AZA Accreditation Standard

(2.6.4) The institution should assign at least one person to oversee appropriate browse material for the collection.

The program should identify if the plants have been treated with any chemicals, pesticides, or herbicides, or grown near any point sources of pollution, and should be screened for, but not limited to, known toxicities to comparable species such as dogs, cats, and humans (see Burrows & Tyrl, 2001) and the potential to cause obstruction of the gastrointestinal tract. Plant materials growing in and around animal habitats should also be evaluated to ensure they are non-toxic as there is a potential for animals to ingest parts of these plants (e.g., leaves, stems, bark, seeds, fruits, etc.).

There is currently no formalized list of approved, safe, or unsafe plant species that are specific to polar bears. The AZA Nutrition SAG and the Association of Zoological Horticulture may be able to provide additional recommendations for safe plant species. Institutions that experience negative consequences from providing a certain browse species to their bears should inform the AZA Bear TAG and Polar Bear SSP Program of the incident so that this information can be widely disseminated.

5.3 Nutritional Evaluations

It is recommended that all zoos and aquariums with polar bears develop diets that are sufficient to meet their nutritional needs in terms of amount, quality, consistency, and include food type enrichment to address some of their behavioral needs. Institutions should contact commercial laboratories to analyze their food ingredients, or physiological samples.

Body condition scoring: Table 9 provides the standard body scoring method used for polar bears by field biologists (provided by Polar Bear Specialist Group; S. Amstrup), that has been validated by continuing field research (Stirling, et al. 2008).

Table 9. Standard body scoring method used for polar bears.

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 with some muscle covering them. The hollow between the pelvis & 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.

Body condition score '3' is the preferred condition for bears in zoos and aquariums. It is appropriate for females to put on additional weight prior to denning-up if they are expecting cubs. Farley and Robbins (1994) have estimated appropriate 'Bioelectrical Impedance Analysis' measurements for polar bear body fat and Hilderbrand, et al. (1998) have described the methodology for using this approach.

Nutrient Serum Values: Tables 10 and 11 provide information about serum concentrations of nutrients and vitamins in polar bears. 25(OH)D is the most valid measure for assessing vitamin D stores because it reflects vitamin D intake and photobiogenesis over several weeks to months. $1,25(OH)_2D$ is more reflective of immediate ingestion or exposure and not stores. Retinol has been used as criteria of vitamin A status. However, serum levels of vitamin A tend to be homostatically controlled at a level that is largely independent of total body reserves (Crissey et al, 2001b). Alpha-tocopherol 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 (Lintzenich, et al. 2006).

Table 10: Serum concentrations of vitamin D metabolites and vitamins A and E (adapted from Lintzenich, et al. 2006)

	Zoo[1]		Zoo[2]		Free-ranging[2]		Zoo[3]	
Nutrients	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	-	nd
1,25(OH)2D, pg/ml	5	18 ±4.2	-	nd	-	nd	-	nd
Retinol, µg/dl	4	25 ±1.8	-	nd	-	nd	1	67
Retinyl palmitate, µg/dl	4	4.9 ±1.3	-	nd	-	nd	-	Trace
Retinyl stearate, µg/dl	4	2.9 ±0.8	-	nd	-	nd	-	Trace
α-tocopherol, µg/dl	4	3362 ±193	32	800±800	56	2101 ±600	1	1459
γ-tocopherol, µg/dl	4	4 0±5.8	-	nd	-	nd	-	nd

nd = no data
1 Crissey et al. 2001b
2 Kenny et al. 1998
3 Schweigert 1990

Table 11: Serum concentrations of total cholesterol, triacylglyceride, HDL cholesterol, and LDL cholesterol (adapted from Lintzenich et al. 2006)

	Crissey et al. 2004		Brannon 1985[1]		Schweigert et al. 1990	
Nutrients	n	Value ±SD	n	Value ±SD	n	Value ±SD
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	-	nd	-	nd
LDL cholesterol, mmol/L	5	6.8±1.49	-	nd	-	nd

nd = no data
[1] data for grizzly bears

The AZA Bear TAG nutrition advisors are currently in the process of collecting blood samples from polar bears in zoos and aquariums to determine more specifically normal vitamin and mineral levels for this species. Results of this research will be shared in future versions of this manual.

Evaluating Patterns in Weight Fluctuations: Most *in situ* polar bears, including those in the high arctic and polar basin, prey on seals year-round (Derocher, et al. 2002; Amstrup, 2003) although food consumption varies depending on season and location. 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). The ability of polar bears to endure prolonged fasting depends on the accumulation or replenishment of fat and lean body mass during the active phase of the year (Atkinson & Ramsay, 1995; Atkinson, et al. 1996).

Dramatic seasonal weight changes demonstrated in polar bears in zoos and aquariums can be modulated through active management of the diet. Examples of weight changes across the year can be found in data from four polar bears housed in southern California (Lintzenich, et al. 2006). The goal of all balanced 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. General feeding patterns in wild bears are largely irrelevant to the zoo and aquarium situation, and so feeding in zoos and aquariums should be regulated by the health and condition of each individual. Lintzenich et al. (2006) provide a tool which is available from the Nutrition Advisors of the AZA Bear TAG to assess stool quality/condition in polar bears that can be used as part of a more comprehensive health assessment of the bears in relation to their diet.

Females should be given every opportunity to raise their cubs, and hand-rearing should be considered as a last resort. If the female is out of the den for prolonged periods of time, or the cubs' cries are sustained, it may be necessary to intervene. Each institution should make a plan before the female is denned up to identify the criteria of if and when intervention will happen.

7.4 Birthing Facilities

In situ cubbing dens vary in size but there is always a maternity den chamber that can typically be found at the upper end of an average entrance tunnel 0.91-2.1 m (3-7 ft) long and 49 cm (1.6 ft) high (Durner et al., 2003); some dens have secondary chambers as well (Durner et al., 2003). Dens average 1.5 m (5 ft) in diameter, 1.48 m (4.9 ft) in length, 1.27 m (4.2 ft) in width, and 0.79-0.91 m (2.6-3 ft) in height (Durner, et al. 2003). Primary chambers usually include a nest-like depression where the adult and cubs spend most of their time and some have more than one exit (Durner et al., 2003).

Ex situ cubbing dens are normally smaller, confined spaces adjacent to larger holding areas in which the female can move around. See Chapter 2, section 2.1 for a discussion on the size of the cubbing den recommended for polar bears in AZA-accredited zoos and aquariums. Remote monitoring of the cubbing den via video camera and microphone is strongly recommended, and can be accomplished by modifying the den to include a camera and low-level lighting prior to parturition. The use of video and audio equipment in the den has proven to be an excellent resource in the management of the cubs, and in sharing the experience with the public in a controlled forum.

Additional heat should not be required within the cubbing den. Cubbing facilities should have a layer of heavy bedding, such as straw that can provide insulation for the female and cubs. However, additional cooling may need to be provided for institutions with high ambient temperatures during the birthing season. If ambient temperatures are abnormally high when the cubs are born, the female may become overheated and abandon them. Ambient temperatures below 18°C (64.4°F) may be appropriate (Kenny & Bickel, 2005). As parturition approaches, animal care staff should ensure that the mother is comfortable in the area where the birth will take place, and that this area is "baby-proofed". A 45 cm (17.8 in) high cubbing gate can be used to prevent the cub(s) from following their mother out of the den when they become mobile (Kenny & Bickel, 2005).

Cubs should not have access to large pools until they are old enough to swim, usually at about 4-5 months of age (Greenwald & Dabek, 2003). However access to pools and water is important and some facilities design in a small pool in the holding area associated with the denning box for this purpose. If possible, pool water levels should be initially lowered to desensitize the cubs to water, and to ensure that they are able to get out of the pool. As with other mammalian neonates, the birthing area and any holding areas associated with it should be free of places where the cubs could fall or get their heads, feet, or body stuck. If hot-wire is used as part of the containment system for the polar bear habitat, consideration should be given as to whether this is needed when cubs are present, and whether there is any possibility of cubs gaining access to live hot wire.

7.5 Assisted Rearing

There are times when both *in situ* and *ex situ* polar bear females are not able to care for their offspring properly. Challenges that have been associated with mother-rearing of polar bear cubs include females not producing sufficient milk, females abandoning the cubs if conditions or birthing facilities are not optimal, and in extreme cases, females killing and eating the cubs in response to extreme stressors in the environment. If it is necessary to hand-rear a young polar bear, every effort should be made to find a conspecific to raise it with as early as possible. Hand-rearing protocols should be established prior to parturition. Each institution should develop a protocol that works best for them based on the staff and facilities available, and should contact the AZA Polar Bear SSP Program Coordinator to provide information from institutions that have successfully hand-reared polar cubs in the past.

Once the decision is made to hand-rear polar bear cubs (or provide any sort of assisted rearing at any time), it will not be possible to return the cubs to the female when their condition improves or they have been stabilized as she will not accept them. If cubs cannot be hand-reared with siblings or similar-aged conspecifics, efforts should be made to introduce them to older cubs that have been successfully weaned from their mothers. Over-familiarization with or over-reliance on human caretakers should be avoided in order to promote normal behavioral development and to increase the likelihood that they will be able to successfully reproduce and rear their own offspring as adults.

Incubation: Polar bear neonates hand-reared at an AZA accredited institution were initially maintained in an incubator at 29-31°C (84.2-87.8°F) until about two weeks of age, when their thermoregulatory abilities improved due to the replacement of their natal coats with longer guard hairs and undercoat (Kenny & Bickel, 2005). At around two weeks of age, the cubs were visibly distressed when kept at these warm conditions, and their vocalizations and abnormal activity levels did not decrease until the temperature was decreased to 18°C (64.4°F) (Kenny & Bickel, 2005).

Infant Formula: If the cubs have not had the opportunity to nurse, then polar bear serum should be administered. It is recommended that serum be administered at 3-5 ml per pound of body weight in two doses spaced 5-10 days apart (G. Hedberg, personal communication, 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®). Medical problems associated with formula composition including rickets/vitamin D deficiency (Kenny et al., 1999), thiamin deficiency (Hess, 1971), lactobezors (indigestible lumps of casein in ursids that can have serious health implications), constipation, dehydration, and bloating (Kenny et al., 1999) have been noted in some cubs. Pediatric vitamins are added to milk formulas by most institutions with experience hand-rearing polar bears, 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 successfully employed by some institutions. Cod liver oil has been frequently added to formulas, however, a number of cubs have been raised successfully without it. Reducing casein (a milk protein) and increasing whey in the formula can help prevent lactobezors. Examples of formulas used successfully to hand-rear polar bears cubs at AZA Accredited Institutions are provided in Appendix I. Comparisons of the nutrient compositions of these formulas are provided in Lintzenich et al., (2006).

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 that the cub be weighed at the same time each day. Quantities of food can gradually be tapered off to 10-20% of body weight by 90 days of age. Initially, feedings should be offered around the clock, evenly spaced 2-3 hours apart. The feeding regime should be reflective of the cub's health status. By one month of age, feedings can be reduced to 5-7 times per day, and the number of feedings should be gradually reduced until weaning.

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 should 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 of age, syringes have been used successfully to offer formula to the cubs.

- *Feeding position*: When young polar bear cubs are fed, they should be placed in a sternal position – on their stomach on a flat surface (table). If cubs are held during feeding (e.g., in an upright or head-back position), there is a greater chance of aspiration and death. When placed in a sternal position, the cub will tend to paddle forward, but will become adjusted to this routine in time. Providing a rolled towel for the cub to push against during nursing will help control this movement.

- *Elimination*: To promote elimination, the cub should be held in a sternal position and the region extending from the belly to the anus gently stroked with a warm, moist cotton ball after every feeding. Only slight pressure is needed to help guide the fecal material through the digestive tract and out of the anal canal. After a week, this procedure should only be performed twice a day. After the cub begins eating solid food, this procedure can be performed once per day. Most cubs will defecate on their own at 8-10 weeks, if not sooner.

Weaning: *In situ* polar bear cubs nurse for up to 2-3 years in the wild. The age at which nursing transitions from nutritional dependence to social bonding with the sow however, is unclear. *In situ* weaning involves both nutritional and behavioral processes, while *ex situ* weaning typically refers to the cessation of bottle-feeding. The process of weaning polar bear cubs off the bottle (i.e., introducing them

to solids) can begin as early as 60 days, although 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 biscuits; ground or soaked foods can be added at first before progressing to dry versions. Fish or fresh meats have been offered to hand-reared polar bear cubs as early as 100-110 days. The weaning process should be gradual, with only one variable changing at a time so that it is clear what effect the changing diet is having on the health and behavior of the cubs. For information on the physical separation of offspring from their mothers see Chapter 4, section 4.1.

Exercise: After hand-reared cubs start walking, it is vital that sufficient space and time be provided to allow them to run and climb, and they should be provided with low climbing structures and a shallow child's swimming pool (at 3-4 months of age). Cubs should be provided with a non-slip surface when learning to walk to prevent splaying. Safe enrichment initiatives should be provided to facilitate play behavior. Items such as stuffed animals (with no small removable parts) and heavy-duty plastic toys may be used. Veterinarian and curatorial staff should be consulted prior to offering novel objects to the cubs. See Chapter 8, section 8.2 for more information on environmental enrichment. Direct human contact (i.e., free contact) with hand-reared cubs should be ended when the cub is four months old in order to prevent injury to caretakers. Protected contact protocols are needed for interactions with all polar bears after this point in time. Cubs should not be allowed to imprint on specific animal care staff. Where possible, hand-reared cubs should be introduced to other bears (preferably polar bears) of similar age and size as soon as possible. This should help elicit more natural behaviors and intra-specific activities. Introductions should follow those outlined for adults.

7.6 Contraception

Contraception techniques can be implemented to ensure that the *ex situ* population of polar bears remains at a healthy size. In addition to reversible contraception, reproduction can be prevented by separating the sexes or by permanent sterilization. In general, reversible contraception is preferable because it allows natural social groups to be maintained while managing the genetic health of the population. Permanent sterilization may be considered for individuals that are genetically well-represented, or for whom reproduction would pose health risks. The AZA Bear TAG and Polar Bear SSP Program should be consulted prior to any permanent contraceptive/sterilization approaches being taken. The contraceptive methods most suitable for polar bears are outlined below.

The progestin-based melengestrol acetate (MGA) implant has been associated with uterine and mammary pathology in felids, and similar pathologies are suspected in other carnivore species (Munson, 2006). Other progestins (e.g., Depo-Provera®, Ovaban®) are likely to have the same deleterious effects. For carnivores, the AZA Wildlife Contraception Center recommends GnRH agonists, e.g., Suprelorin® (deslorelin) implants or Lupron Depot® (leuprolide acetate), as safer alternatives, although dosages and duration of efficacy have not been systematically evaluated for all species. GnRH agonists can be used in either females or males, and side effects are generally associated with gonadectomy, especially weight gain, which should be managed through diet. Suprelorin® was developed for domestic dogs and has been used successfully in polar bears. Links to more details on products, application, and ordering information can be found on the AZA Wildlife Contraception Center (WCC) webpage: www.aza.org/wildlife-contraception-center/.

Gonadotropin releasing hormone (GnRH) agonists: GnRH agonists (e.g., Suprelorin® implants, or Lupron Depot®) achieve contraception by reversibly suppressing the reproductive endocrine system, preventing production of pituitary (FSH and LH) and gonadal hormones (estradiol and progesterone in females and testosterone in males). The observed effects are similar to those following either ovariectomy in females or castration in males, but are reversible. GnRH agonists first stimulate the reproductive system, which can result in estrus and ovulation in females or temporary enhancement of testosterone and semen production in males. Down-regulation then follows the initial stimulation. The stimulatory phase can be prevented in females by daily Ovaban administration for one week before and one week after implant placement (Wright et al., 2001).

GnRH agonists should not be used during pregnancy, since they may cause spontaneous abortion or prevent mammary development necessary for lactation. They may also prevent initiation of lactation by inhibiting progesterone secretion, although effects on established lactation are less likely. New data from

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Complete Polar Bear Bibliography and Reference List:

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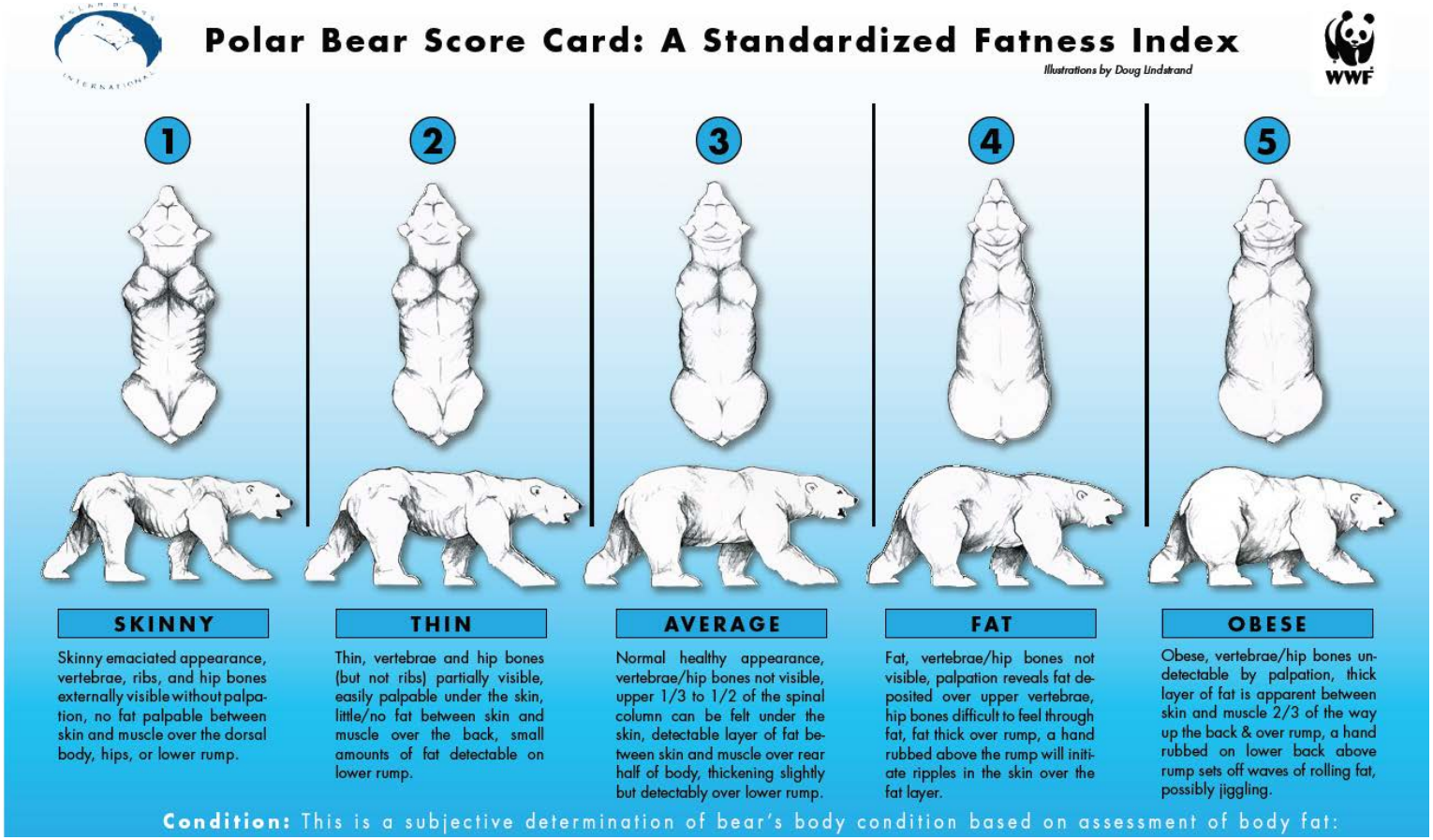
Appendix B: Polar Bear Body Condition Score Sheet



Appendix F: Statement on the Safety of Feeding Anadromous Fish

Fish are a standard part of polar bear diets in zoos and aquariums. 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. 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.

Since that time, concern for polar bear health has lead institutions to question the feeding of anadromous fish (fish that swim upstream), like salmon and trout. Investigation of this issue has lead to new recommendations for feeding live or fresh anadromous fish from the Pacific Northwest to polar bears.

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 carry the fluke with this *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 and therefore 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 does not 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. 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 sun bears 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 completely frozen (3 days of freezing for large salmon – longer for larger fish) if are harvested from any location or fresh AF harvested from areas other than the Pacific Northwest.

Detection and diagnostics: If an institution is going to feed PNWAF fresh or live, it is important to screen and deworm 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 ricettsial 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 days
  - Or Praziquantel/pyrantel/febental (Drontal Plus) used according to manufacturer recommendations. Recommendations in canids warn against using in pregnant animals, dogs less than 2 pounds, or puppies less than 3 weeks of age.

Appendix G: Nutritionally Complete Food and Meat Mix Specifications

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.

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	-

[a]Suggested minimum polar values complied by the polar bear nutrition working group.

Specification 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.

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	-

[a]Suggested minimum polar values complied by the polar bear nutrition working group.

Appendix I: Polar Bear Cub Formula Examples

Institution A: Raised 1 bear from 1 day of age.

Day 1-5: Ratio of Esbilac: water by volume = 1:3

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

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

Day 6-7: Ratio of Esbilac: water by volume = 1:2.5

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

Added cod liver oil at 5ml/day

Day 8-14: Ratio of Esbilac: water by volume = 1:2

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

Added cod liver oil at 5ml/day

Day 15-28: Ratio of Esbilac: water by volume = 1:1.5

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

Added cod liver oil at 5ml/day

Day 29+: Ratio of Esbilac: water by volume = 1:1

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

Added cod liver oil at 7.5ml/day (increased to 10ml/day Day 58)

Institution B: Raised 1 bear from 5 days of age.
Institution B'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

Institution C: Raised 2 bears from approximately 90 days of age.

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