Summary of Nutrition Guidelines for

Otters in Zoos, Aquaria, Rehabilitation, and Wildlife Sanctuaries

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Photograph: Spotted-necked otter, Jenna Kocourek, Little Rock Zoo

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1. OTTER NUTRITION

Adequate nutrition is an essential for optimal husbandry. Improper feeding can severely affect health and well-being of captive animals (Hatt 2000). Improved nutrition has often positive effects on longevity, disease prevention and resistance, growth and reproduction (Ratcliffe 1963, Dierenfeld 1997).

A formal nutrition program is recommended to meet the behavioral and nutritional needs of all animals. Diet formulation criteria should address the otters' nutritional needs, feeding ecology, as well as individual and natural histories to ensure that species-specific feeding patterns and behaviors are stimulated. In specific, diet formulation should account for animal preferences, body weight, exercise, physical condition, environmental/seasonal changes, behavioral considerations, diet item availability, gastrointestinal tract morphology, as well as the actual nutrient requirements.

1.1 Nutrient Requirements

Metabolic studies examining the exact nutrient requirements have not been done for any otter species. Conducting these metabolic studies, which require collection of feces, urine, and blood samples under laboratory conditions, to assess nutrient requirements for wild species are difficult. For this reason, target nutritional values for otters are based on several sources and use domestic and other small carnivore pelt producing species as models.

The cat is typically used to establish nutrient guidelines for carnivorous animals. The National Research Council (NRC 2006), Association of American Feed Control Officials (AAFCO 1994), and Waltham Center for Pet Nutrition (Earle & Smith 1993) have provided recommendations for cats. A limited amount of information is provided by the NRC publication for mink and foxes (1982), which represents the requirements of another mustelid species. In addition, target nutrient values for one of the species in question has been reported elsewhere (Maslanka and Crissey 1998). Table 1 lists dietary nutrient ranges for otters, based on a variety of sources.

The mink as a model animal for otters was tested with *Lutra lutra* and showed a lower digestive efficiency and faster passage times for the otter (Ruff 2007) –suggesting use of the higher amounts of given ranges for mink should be used for otters.

Another method of assessing nutrient requirements is to consider natural feeding ecology. Presuming the unproven assumption of diet optimality in free-ranging animals, as the optimal foraging theory suggests, appropriate approximate nutrient requirements can be derived by analyzing in-situ diets (Dierenfeld 1994, Krebs et al. 1978). Insight into problematic nutrient ranges in *ex-situ* nutrition (in zoos etc.) can be found through comparing the ex-situ with in-situ nutrient ranges.

Table 1: Target nutrient ranges for otter species (dry matter basis).

Nutrient	Otters[1]
Protein (%)	19.7-32.5
Fat (%)	9.0-30[2a]
Linoleic Acid (%)	0.5-0.55
Vitamin A (IU/g)	2.44-10
Vitamin D (IU/g)	0.25-1.0
Vitamin E (mg/kg)	27-120
Thiamin (mg/kg)	1.0-5.6[1b]
Riboflavin (mg/kg)	1.6-4.25
Pantothenic acid (mg/kg)	5.0-8.0
Niacin (mg/kg)	9.6-60
Pyridoxine (mg/kg)	1.6-4.0
Folacin (mg/kg)	0.2-1.3
Biotin (mg/kg)	0.07-0.12
Vitamin B_{12} (mg/kg)	0.02-0.035
Calcium (%)	0.29-1.0[1c]
Phosphorus (%)	0.26-0.8[1c]
Potassium (%)	0.4-0.6
Sodium (%)	0.05-0.4
Magnesium (%)	0.03-0.08
Iron (mg/kg)	80-114
Zinc (mg/kg)	50-94
Copper (mg/kg)	5.0-8.8
Iodine (mg/kg)	0.35-2.2
Selenium (mg/kg)	0.1-0.4

[1] Cat NRC (2006), Legrand-Defretin & Munday (1993), Cat AAFCO (1994); Maslanka & Crissey, 1999; Mink NRC (1982); Fox NRC (1982) (for mink and fox NRC protein is range of growth and maintenance, vitamins are for growth, and minerals for growth and maintenance).

[1a] Lewington (2002) indicated that lactation demand on female mink (*Mustela*) may require up to 45.7% CP on a dry matter basis (based on a calculated 83% protein digestibility).

[1b]Blomqvist (2001) has indicated that wolverines (*Gulo gulo*) may have a higher requirement for thiamin than other mustelids.

[1c] Authors of this chapter would caution feeding diets with 0.29% calcium and 0.26% phosphorus as the Cat NRC 2006 suggests.

Table 2: Calculated nutrient composition of *Lutra lutra in-situ* and *ex-situ* diet (dry matter basis), *in-situ* values can be used as additional guideline with table 1.

	mean		range (30-60% of values)	
	in-situ	ex-situ	in-situ	ex-situ
Energy (GE) (kJ/100g)	2055 ±217.6	2220 ±254.2	2040 - 2172	2195 - 2308
Crude fat (g/100g)	19.1 ±5.7	32.2 ±6.7	18.0- 21.8	29.3 - 34.6
Crude protein (g/100g)	72.7 ±7.2	57.5 ±7.4	72.2 - 74.5	53.6 - 61.7
Calcium (g/100g)	1.0 ±0.6	1.1 ±0.6	0.9 - 1.2	0.6 - 1.6
Magnesium (g/100g)	0.3 ±0.3	0.2 ±0.1	0.3 - 0.4	0.2 - 0.3
Phosphorus (g/100g)	1.2 ±0.5	1.2 ±0.4	1.3 - 1.4	1.1 - 1.4
Potassium (g/100g)	1.3 ±0.4	1.1 ±0.2	1.3 - 1.4	0.9 - 1.2
Sodium (g/100g)	0.4 ±0.1	0.4 ±0.2	0.4 - 0.5	0.3 - 0.4
Zinc (mg/kg)	93.7 ±41.4	75.0 ±18.5	69.1 - 115.1	67.5 - 82.0
Vitamin A (IU/kg)	21.1 ±9.3	38.0 ±29.6	18.3 - 24.2	25.1 - 36.6
Vitamin E (mg/kg)	106 ±73.0	71.5 ±74.5	88.4 - 114.5	36.4 - 63.7
Vitamin B_1 (mg/kg)	2.6 ±1.2	4.4 ±2.6	1.9 - 3.6	3.2 - 4.7

± standard error / GE: Gross Energy

1.2 Energy intake and food amount

Primarily piscivorous, otters have high metabolic rates, rapid digestion, and have been found to spend 41 - 60% of their time involved in feeding or foraging activities (Hoover & Tyler 1986; Davis et. al 1992; Kruuk 1995; Reed-Smith 2010, Ruff 2007). Duplaix-Hall (1975) found that otters (unidentified species) in the wild rarely ate more than about 500g of food at a time and that they consumed approximately 20% of their own body weight daily. Kruuk (1995) reviewed his and other study results indicating that *ex-situ* (zoo/aquarium) populations of *Lutra lutra* consuming between 11.9-15% of their body weight maintained a healthy weight. Ruff (2007) measured digestible energy intake in 14 otters (*Lutra lutra*) over a period of several years under an ad libitum regimen and found an intake of, on average, 721kJ/kg body mass $(BM)^{0,75}$ /d, comparable to the calculation of Pfeiffer (1996) who gives an average of 707kJ/kg body mass $(BM)^{0,75}$ /d. Ben-David et al. (2000, 2001a and b) reported success maintaining *L.*

canadensis in good condition using 10% of their body weight as a guide for the basis of their maintenance diet. Keep in mind that the amounts described are based on the energy density of the diet. In an *ex-situ* population study of the *P. brasiliensis*, Carter and Rosas (1997) determined that an adult consumed roughly 10% (range 6 - 16%) of their body weight daily and a sub-adult consumed 13.4% (range 8 - 18.9%). Earlier studies (Zeller 1960; Best 1985) reported similar findings with adults and sub-adults daily consuming 7 - 9.6% and 12.9% of their body weight, respectively.

Amounts eaten can vary with energy density of the diet, ambient temperature, sex, season and activity level changes, but if food is refused for 24 hours, this could be a sign of illness. Body weight and condition should be measured regularly and daily amounts and food types eaten should be monitored and recorded.

1.3 Changing Nutrient Requirements

Age: An animal's diet should be developed to maintain optimal weight. Weight gain and normal physical development for a young animal or weight loss for an over conditioned animal should also be considered. Diets for young or senescent adults should take into account their activity level, dental development and/or condition. Many recommend that fish with a higher fat content should be offered growing cubs, particularly if low-fat fish are typically fed by an institution. This has been particularly true for institutions working with the *Lontra longicaudis* where deaths have been reported due to insufficient fat content of diets fed cubs (Nidasio personal knowledge).

Sex: Sexual dimorphism occurs in most otter species. Females are smaller than males resulting in a higher energy demand for females per kg body mass. For *Lutra lutra* a mean digestible energy intake of 738kJ/kg $BM^{0,75}$/d was found for females, 698kJ/kg $BM^{0.75}$/d for males (Ruff 2007).

Reproduction: There is an increased need for energy during lactation to support milk production. This energy can be provided through the diet or through the tissue of the dam. Tumanov & Sorina (1997) supported the use of high-energy diets for lactating female mustelids. Fat is the most concentrated source of energy in the diet. For lactating females, fat levels in the diet may be increased to support lactation (see below for exceptions) and also to provide increased energy to minimize mobilization of body stores and metabolic stress associated with milk production. Diet increases for lactating otters should be based on past experiences with individual otters and/or observed body weight loss (mobilization of tissue to support lactation). To date, institutions have typically increased the amount of fish offered a lactating female versus simply increasing the fat content by switching the type of food offered. When instituted, an increase of 10 - 30% is the accepted rule.

P. brasiliensis: Hagenbeck and Wünnemann (1992) reported that lactating females at the Hagenbeck Tierpark generally increased their food consumption from 4.41 - 6.61 lbs/day to

13.23lbs/day (2 - 3kg/day to 6kg/day). They also reported increasing vitamin supplements during pregnancy/lactation and calcium supplementation during lactation (Sykes-Gatz 2005).

The energy requirements of a pair of giant otters, including a pregnant female, at the Philadelphia Zoo also increased during pregnancy and lactation. At this time, the energy intake of the pair increased to 246kcal/kg $BW^{0.75}$ (~2.75kg fish/animal fed at a ratio of 1:2 low- to high-fat fish). Fifty days postpartum and with one surviving cub, the intake of the pair was 236kcal/kg $BW^{0.75}$ (~3kg fish/animal fed at a ratio of 1:4 low- to high-fat fish). The female exhibited a preference for herring, trout, and catfish (K. Lengel, personal communication). It appears that feeding behaviors of *ex-situ* populations of reproductive *P. brasiliensis* mimic those of their wild counterparts. Rosas et al. (1999) found that during the birthing season, the diet of wild otters included a higher proportion of fish in the order Siluriformes (catfishes), which are higher in fat (37 - 41% fat DMB; Silva 1993) than fish in the order Percoidei (perch) (22 - 31% fat DMB – Twibell & Brown 2000),which are commonly fed on in the wild. Siluriformes are also higher in fat than Chiclidae (tilapia) (21 - 32% fat DMB; Toddes 2005-2006 unpublished analysis), which are the low-fat fish commonly fed to otters at the Philadelphia Zoo.

Weight: An animal's body weight and condition should be monitored regularly and diets adjusted accordingly. Some institutions report seasonal changes in appetite of some otters, but not in the majority of animals. At this time, further research into seasonal nutritional requirements is required.
For *Lutra lutra* data are available (Ruff 2007): seasonal differences occurred with lower intake rates of digestible energy being consumed in summer (691 KJ/kg $BM^{0,75}$/d) than in winter (750 kJ/kg $BM^{0,75}$/d).

Weight Loss: Otters should be maintained in appropriate condition but, they are prone to gaining excessive weight in captivity. Tarasoff (1974) reported subcutaneous fat deposits primarily at the base of the tail and caudally on the rear legs, with smaller deposits around the genitalia and in the axillary regions. Note: Obesity is *Lutra lutra* is seldom reported (Alen 1996), even under an ad libitum feeding regimen (Ruff 2007).

There are several ways to approach formulating a weight loss diet for otters. Depending on the food items available, the feeding situation (fed alone or in a group), and the amount of weight loss desired, one or more of the following approaches may be appropriate.

- <u>Feed less total food</u>: By reducing the amount of total food offered, weight loss may occur. This practice is confounded by the competition aggression observed in most otters, and particularly *A. cinereus* and *P. brasiliensis* groups, around feeding time and the potential for this to increase when less food is offered.

- <u>Add more water to the diet:</u> By providing a diet that contains more moisture, the total calories in the diet are diluted and this may allow for weight loss. The otter can consume the same amount of total diet, but will actually be consuming fewer calories.

- Increase the "bulk" of the diet: By adding indigestible or lower calorie items to the diet, the total "bulk" of the diet can be increased, effectively diluting the calories in the diet. The otter can consume the same amount of total diet, but will actually be consuming fewer calories.

- Offer lower calorie items: Lower calorie items can be substituted in the diet. For example, fish varies in energy content from species to species. If weight loss is desired, a leaner fish, such as pollock, could be substituted for a fattier fish, such as herring or capelin, to reduce total calories in the diet. This would be the preferred method for all otter species fed fish.

DIETS AND FEEDING

The one best diet for any of the otters of *ex-situ* populations has not been found and requires further research. A good diet for an otter is one that meets nutrient needs while allowing for appropriate weight management and normal behaviors.

2.1 INGREDIENTS

Fish

Current recommendations for most otters are that a variety of fish species should be offered 3 - 4 times a week, preferably daily. Daily is required for *P. brasiliensis*, *L. maculicollis, A. capensis*, *L. canadensis L. lutra,* and suggested for all species). Reliance on multiple fish species, versus one or two, will prevent animals from developing strong preferences and help in switching them over to new sources if one fish type becomes unavailable as well as provide a better nutritional balance. Whole fish should be used. ***P. brasiliensis****:* whole fish should be the sole dietary item offered.

Only good quality fish should be offered. The fish source(s) and/or vendor(s) should be examined closely to assess their handling practices, ensure that quality handling guidelines are being met, and that the fish is considered human grade. Historical use of a type of fish by zoos and aquariums does not ensure it is an adequate diet ingredient, and only careful inspection of handling practices and the fish itself ensures consistent safety and quality.

The process of fish storage (freezing), thawing, and preparation, can lead to fish nutrient loss, particularly vitamins B_1 and E, and especially in fish with high fat and/or high thiaminase content (Crissey 1998; Merck 1986). If you freeze the fish yourself guarantee a fast freezing process. Store the fish at very cold temperatures, feed as soon as possible, and optimize the thawing process by allowing the fish to thaw in a refrigerator.

Meat ingredients

Most diets in institutions in the United States currently include horsemeat products, or alternative beef-based products which are available in addition to nutritionally complete dry and wet cat foods; European facilities typically feed fish and some “whole carcass food” such as chicks, chicken necks, mice, rats, or beef rumen daily.

Plants

Plants considered toxic to humans or other animals should be considered toxic to otters. Loquat (Weber and Garner 2002) consumption has proven fatal to Asian small-clawed otters. Otters are obligate carnivores but they will eat some vegetative matter such as berries and/or consume vegetation or other foreign material out of boredom or while exploring their environment. Some products, such as carrots are routinely used by U.S. and European ex-situ facilities as low-calorie enrichment items. These can occupy the otters in foraging activities but do not contribute any significant nutritional value to their diet.

Dental care ingredients

A. capensis, *L. canadensis*, *L. lutra* and *L. maculicollis*: Hard dietary items should be routinely incorporated for dental health. These can include: hard kibble, crayfish, crabs, chicken necks, ox/horse tails, beef heart, beef rumen, partially frozen fish, bony fish, day-old chicks, mice, rib bones, canine dental bones, or similar items. This also may be valuable for the other otter species.

Species-appropriate Foraging and Feeding, Enrichment

Live fish and crustaceans can and should be provided, if possible, on a regular basis, at least as enrichment on a weekly basis. However, due to the risks of live fish or crayfish transmitting disease or parasites, policies regarding the feeding of live prey should be established by each facility. If these items are used, they should be obtained only from known, institutionally approved sources. Where live prey are used, provisions in the exhibit should be made to allow these prey species a place to hide from the otters, thus forcing the otters to use their hunting skills and extending the time of activity.

There also are a variety of puzzles and other feeding devices described in the literature that can be adapted for use in river otters. Alternatively, feeding tubes can be built into exhibits that randomly release live prey or food items into the exhibit.

With the exception of *P. brasiliensis* (which should only be fed an all fish diet), otters will sample a variety of food groups, especially if introduced to them at an early age; cat kibble, worms, crickets, vegetables, berries, mice, chicks, etc., can all be added to the diet as enrichment. Due to the possible formation of uroliths, foods high in calcium oxalates should be avoided (e.g., beans, carrots, celery, leafy greens, sweet potato, berries, peanuts, among others), particularly for *A. cinereus*. The use of these items for enrichment scatter feeds for North American river otter is acceptable on a limited basis, but the overall nutrient and caloric intake, body weight and condition of the animal(s) should be taken into consideration.

2.2 SUPPLEMENTATION

Vitamin A was found to be one of the most over-supplemented nutrients in zoo diets (Dierenfeld 1994) which was also the case in *Lutra lutra* study (Ruff 2007). Vitamin A is fat soluble,is stored in the body fat and can cause toxicity. Vertebrate prey given in whole form contains in general vitamin A levels meeting the recommendations and should not be added through a supplement. This is also important because a direct antagonism between Vitamin A and E is reported (Mazzaro et al 1995) and vitamin E often does not meet requirements in ex-situ diets.

Vitamin E is destroyed to a large extent when fish is stored, also when it is frozen (see 2.1). Therefore Vitamin E levels should be carefully checked and supplemented. When frozen-thawed fish is included in the diet as more than 33% of the total diet (wet weight) Vitamin E should be supplemented (Engelhardt & Geraci 1978 for fish-eaters: 100 IU / kg of fish wet weight basis).

V*itamin B1 (thiamin)* is destroyed by thiaminase, a problem mainly when certain fish species (carp, roach, herring, mackerel, smelt) and day-old-chicks are given because of their high content of thiaminase (an enzyme destroying vitamin B). So supplementing vitamin B1 is recommended keeping in mind not to give it directly with feed stuffs high in thiaminase but with other food items. Bernard & Allen 1997 recommend in general for fish-eaters 20-30 mg Vitamin B1/kg fish fed (fresh weight as fed basis), this amount should be adjusted by checking the thiaminase amount fed.

Many *ex-situ* institutions use multivitamin supplements in various dosage forms and from numerous manufacturers. No special mixtures for otter species exists, often those for fish eaters are used. Please check your supplement carefully for above mentioned vitamins.

2.3 Special concerns

P. brasiliensis: A variety of good quality, fresh-water fish low in thiaminase and fat should be offered as the main diet (Wünnemann 1995a). Saltwater fish, high in fat, should only be offered occasionally. This species should be fed 3 - 5 times daily. Typically, 2 - 3kg (4.4 - 6.6lbs) of fish should be fed daily to each adult, based on energy density. Results of a survey of facilities housing this species indicate that all of these institutions offer fish daily (thawed, frozen, live, and/or freshly caught) as the main diet. Fish species offered include the following: rainbow trout (*Salmo gairdneri*), carp (*cyprinus carpio*), river fish (unidentified), tilapia, redeye (*Rutilus rutilus*), common bream (*Abramis brama*), herring* (*Culpea harengus*), mackerel* (*Scomber scombrus*), felchen (*Coregonus albula*), and channel catfish (*Ictalurus punctatus*). Fish species marked with an asterisk (*) can be used as a training reward or for vitamin delivery.

Lutra lutra: Urolithiasis due to ammonium urate calculi is a significant problem in captive Eurasian otters occurring in up to 69.2% of the captive population (Keymer et al. 1981, Weber 2001). A low urinary pH and a high uric acid and ammonium concentration in urine are risk factors. Renal uric acid excretion is influenced directly from purine intake. So food ingredients high in purine should be avoided (e.g. yeast, herring, smelt, most internal organs). To reduce the urinary ammonium concentration, the protein intake should be adequate to recommendations, paying particular attention to a high quality of the protein and a good digestibility (Ruff 2007).

Single case studies of ***L. canadensis*** also have described uric acid calculi (Groove et al. 2003) but not to the same extent seen in *L. lutra and A. cinereus*.

A. cinereus: up to 66.1% develop kidney stones, mainly composed of calcium oxalate (Calle 1988). Several studies have been performed with all-fish diets, various additives to adjust urine pH, and commercial feline diets designed to minimize incidence of calcium oxalate stone in cats, but little long term success has been achieved. It appears most prudent to feed low oxalate content diet ingredients, include complete feeds designed to minimize opportunity for oxalate stone formation (increase urinary pH, increase urinary citrate excretion, maintain appropriate intake of P, Mg, and pyridoxine, and maintain adequate overall intake and appropriate body condition). In addition, increasing the water temperature of the water available for swimming and drinking may also provide some beneficial diuretic effects.

2.4 Feeding Schedule

Due to their naturally nutrient dense diet, rapid transit time of food through the intestinal tract, feeding style of frequent, small amounts, and generally high activity level – it is recommended that otters be fed at least twice a day and preferably three or more times daily (including enrichment or training feeds).
P. brasiliensis should be fed 3 - 5 times per day. Frequent feeding prevents consumption of spoiled food, accommodates their rapid digestion (Ormseth & Ben-David 2000), and can stimulate increased activity in these generally active and curious species.

In addition to feeding smaller amounts frequently, it is recommended that a portion of the daily diet be fed as part of enrichment or husbandry training activities. At least one of the daily feedings, or part of a feeding, should be scattered to encourage foraging (except for giant otter). Timing of foraging opportunities and items offered should be varied to prevent habituation. All uneaten food should be removed before it spoils; this may be daily or more frequent in warm climates or seasons.

P. brasiliensis: Food for *P. brasiliensis* should not be scatter fed, as they do not forage on land and non-living food left uneaten in pools can be difficult to find. A portion of the daily diet can be used for daily training sessions with this species.

2.5 Sample Diets

Nutrient requirements are unknown for otter species, so existing dietary recommendations are adapted from experience of successful keepers. In table 3 sample diets for *A. cinereus, A. capensis, P. brasiliensis, L. Canadensis, L. lutra, and L. maculicollis* are listed; table 4 shows the nutrient analysis of these diets.

Table 3: Sample diet from AZA (Association of Zoos and Aquariums) institutions of otter species as fed daily*.

Species	Common Name	Institution	Food Item[1]	grams/day	% in diet
A. cinereus	Asian small-clawed	Institution 1	Capelin	550	20.72
		Diet #1	Silversides	1000	37.68
		9 otters	Lake Smelt	450	16.96
		4 adults, 1 weaned, 5 cubs	Herring	650	24.49
			Thiamin supplement	0.8	0.03
			Vitamin E supplement	3	0.11
			Total	2653.8	100
		Institution 1	Silversides	800	26.54
		Diet #2	Capelin	800	26.54
		9 otters	Mackerel	450	14.93
		5 adults, 4 cubs	Crayfish	210	6.97
			Mice	450	14.93
			Shrimp	240	7.96
			Thiamin supplement	0.9	0.03
			Vitamin E supplement	3.0	0.10
			Pet tablets	0.42	0.01
			Mealworms	60.0	1.99
			Total	3014.3	100
		Institution 1	Silversides	800	25.70
		Diet #3	Capelin	650	20.89
		11 otters	Mackerel	350	11.25
		5 adults, 4 nursing	Ocean Smelt	400	12.85
		Females, 2 cubs	Crayfish	500	16.07
			Mice	230	7.39
			Shrimp	130	4.18
			Mazuri Mammal Tablets	1.9	0.06
			Mealworms	50	1.61
			Total	3111.9	100
	Asian-small clawed	Institution 1	Capelin	100	19.16
		Diet #4	Silversides	200	38.31
		2 otters - adults	Mackerel	40	7.66
			Clams, quahog whole	40	7.66
			Mice	50	9.58
			Sardines	40	7.66

Species	Common Name	Institution	Food Item[1]	grams/day	% in diet
			Shrimp	40	7.66
			Mealworms	11.4	2.18
			Mazuri Mammal Tablets	0.61	0.12
			Total	522.01	100
A. capensis	African Cape clawless	Institution 2	Herring	210	14.83
		0.1	Capelin	357.5	25.24
			Lake Smelt	64.8	4.58
			Trout	129.7	9.16
			Rock Crabs	129.7	9.16
			Mahogany clams	356.7	25.12
			Frog Legs	64.8	4.58
			Earthworms	35.1	2.48
			Live Minnows	67.7	4.72
			Mazuri Vitamin E tablet	1.4	0.1
			Thiamin tablet	0.4	0.03
			Total	1417.4	100
		Institution 2 1.0	Herring	210	11.22
			Capelin	357.5	19.10
			Lake Smelt	518.9	27.71
			Trout	129.7	6.93
			Rock Crabs	129.7	69.3
			Mahogany clams	356.7	19.06
			Frog Legs	64.8	3.46
			Earthworms	35.1	1.88
			Live Minnows	67.1	3.58
			Mazuri Vitamin E tablet	1.7	0.09
			Thiamin tablet	0.8	0.04
			Total	1872.0	100
P. brasiliensis	Giant	Institution 3 Male	Rainbow Trout	1362	67.52
			Herring	340	16.86
			Tilapia	113	5.60
			Catfish	200	9.92
			Multi-vitamin/mineral tablet	1.3	0.06
			Thiamin tablet	0.3	0.01
			Vitamin E gelcap	0.47	0.02
			Total	2017.07	100
		Institution 3 Female	Rainbow Trout	1816	61.81
			Herring	681	23.18
			Tilapia	339	11.54
			Catfish	100	3.40
			Multi-vitamin/mineral tablet	1.3	0.04
			Thiamin tablet	0.3	0.01
			Vitamin E gelcap	0.47	0.02
			Total	2938.07	100
		Institution 3	Rainbow Trout	908	59.97

Species	Common Name	Institution	Food Item[1]	grams/day	% in diet
		Young Adult (18-24 months)	Herring	0	0
			Tilapia	454	29.99
			Catfish	150	9.91
			Multi-vitamin/mineral tablet	1.3	0.09
			Thiamin tablet	0.3	0.02
			Vitamin E gelcap	0.47	0.03
			Total	1514.07	100
		Institution 3 Post Weaning (9-12 months)	Rainbow Trout	1362	89.19
			Herring	0	0
			Tilapia	113	7.40
			Catfish	50	3.27
			Multi-vitamin/mineral tablet	1.3	0.09
			Thiamin tablet	0.3	0.02
			Vitamin E gelcap	0.47	0.03
			Total	1527.07	100
L. canadensis	Nearctic	Institution 4	Natural Balance Carnivore 10% fat	275.5	35.43
			IAMS weight control cat food dry	104	13.20
			Capelin	209	26.50
			Herring	124.5	15.80
			Egg, hard-boiled	55.5	7.0
			Mice, weanling (average wt.16 g)	16	2.0
			Stuart Products Thiamin-E paste	0.55	0.7
			Total	789.5	100
L. maculicollis	Spotted-necked	Institution 5	Natural Balance Carnivore 10% fat	50	41.02
			IAMS weight control cat food dry	150	13.67
			Trout (150 g 3x/wk)	34.2	17.58
			Squid (120 g 3x/wk)	51.4	14.06
			Yam	25	6.84
			Carrot	25	6.84
			Total	365.6	100
L. longicaudis annectens	Neotropical River Otter	Institution 6 Diet # 1 1.1	Chicken		39
			Pacific Sierra		60
			Calcium Carbonate		0.92
			Nutro (vitamin/mineral)		0.08
		Institution 6 Diet # 2 CUBS 2 Cubs 1 month to adult size	Chicken meat		61.00
			Pacific sierra		38.00
			Calcium carbonate		0.92
			Nutro (vitamin/mineral supplement)		0.08

Species	Common Name	Institution	Food Item[1]	grams/day	% in diet
		Institution 7	Chicken		58.00
		Diet # 1	Pacific sierra		28.00
		1,1	Proplan Adult Dog		14.00
	Neotropical	Institution 8	Chicken		56.00
		Diet #1	Mojarra		43.00
		1.1	Calcium Carbonate		0.3
			Nutro (vitamin/mineral)		0.3
		Diet # 2	Chicken		32.00
		4.2	Pacific sierra		67.00
			Calcium Carbonate		0.5
			Nutro (vitamin/mineral)		0.8
		Diet # 3	Chicken meat		61.00
		Cubs	Pacific sierra		38.00
		4.1.0	Calcium carbonate		0.92
			Nutro (vitamin/mineral supplement)		0.08
			Cattle heart		2.5
			Cattle liver		2.5
			Vitamin supplement		
			Total		100
L. lutra	Eurasian	Institution 9	Day-old-chicks		15
			Bream		10
			Ground beef		65
			Cattle heart		2
			Oat flakes		3
			Wheat bran		2
			Carrot		2
			yeast		1
			Total		100
		Institution 10	Bream		50
			Roach		50
			vitamin supplement		
			Total		100
		Institution 11	Day-old-chicks		12.5
			Trout		31.25
			Ground beef		6.25
			Cattle heart		6.25
			chicken		12.5
			Rabbit		6.25
			Mouse		6.25
			Rat		6.25
			Guinea pig		6.25
			carrot		6.25
			Total		100

Species	Common Name	Institution	Food Item[1]	grams/day	% in diet
		Institution 12	Day-old-chicks		25.00
			Bream		30.00
			Rumen		40.00
			Cattle heart		2.5
			Cattle liver		2.5
			Vitamin supplement		
			Total		100

[1]Mazuri PMI Nutrition International. Brentwood, MO 63144; Natural Balance Pet Foods, Inc. Pacoima, CA 91331; P&G Pet Care (IAMS), Cincinnati, OH 45220; Reliable Protein Products, Phoenix, AZ 85050.

* The AZA SCTAG does not specifically endorse the use of any mentioned products.

Diet suggestions for other species will be offered in future editions of this document.

Table 4: Nutrient analysis of the sample diets[1] (dry matter basis).

Nutrient	Institution 1 Asian SC 1	Institution 1 Asian SC 2	Institution 1 Asian SC 3	Institution 1 Asian SC 4	More Carnivorous[1]
Protein (%)	38.73	35.6	40.5	40.7	19.7-32.5
Fat (%)	13.95	9.87	10.40	11.76	9.0-30
Vitamin E (mg/kg)	346	385	234	464	27-120[1a]
Thiamin (mg/kg)	151	134	203	402	1.0-5.6[1a]
Calcium (%)	1.2	0.96	1.0	1.3	0.29-1.0[1b]
Phosphorus (%)	1.1	0.75	0.94	1.0	0.26-0.8[1b]
Iron (mg/kg)	40.7	45.4	41.3	72.3	80-114
Nutrient	Institution 2 African CC 0.1	Institution 2 African CC 1.0			More Carnivorous
Protein (%)	66.4	68.3			19.7-32.5
Fat (%)	20.6	19.7			9.0-30
Vitamin E (mg/kg)	457	418			27-120[1a]
Thiamin (mg/kg)	171	234			1.0-5.6[1a]
Calcium (%)	1.2	1.3			0.29-1.0[1b]
Phosphorus (%)	1.1	1.2			0.26-0.8[1b]
Iron (mg/kg)	296	248			80-114
Nutrient	Institution 3 Giant – male	Institution 3 Giant - female	Institution 3 Giant - YA	Institution 3 Giant - PW	More Carnivorous
Protein (%)	53	53	53	53	19.7-32.5
Fat (%)	39	39	36	41	9.0-30
Vitamin E (mg/kg)	636	410	812	754	27-120[1a]
Thiamin (mg/kg)	169	110	215	205	1.0-5.6[1a]
Calcium (%)	2.3	2.2	3.1	2.0	0.29-1.0[1b]
Phosphorus (%)	1.7	1.6	2.0	1.5	0.26-0.8[1b]
Iron (mg/kg)	72	68	89	69	80-114
Nutrient	Institution 4 NARO	Institution 5 Spot-necked			More Carnivorous
Protein (%)	49.0	45.6			19.7-32.5
Fat (%)	28.7	19.5			9.0-30
Vitamin E (mg/kg)	448	263			27-120[1a]
Thiamin (mg/kg)	108	14.5			1.0-5.6[1a]
Calcium (%)	1.4	1.3			0.29-1.0[1b]
Phosphorus (%)	1.0	0.6			0.26-0.8[1b]
Nutrient	Institution 6 NEO - Adults	Institution 6 NEO - Cubs	Institution 7 NEO - Adults	Institution 8 NEO - Adults	More Carnivorous
Protein (%)	35	42	49	42	19.7-32.5
Fat (%)	21.5	31	29.6	29	9.0-30
Vitamin E (mg/kg)	--	--			27-1201a
Thiamin (mg/kg)	--	--			1.0-5.61a
Calcium (%)	1.5	1.3	0.58	0.72	0.29-1.01b
Phosphorus (%)	1.5	1.25	0.61	0.46	0.26-0.81b
Iron (mg/kg)	--	--			
Nutrient	Institution 8 NEO - Adults	Institution 8 NEO - Cubs			More Carnivorous
Protein (%)	32	42			19.7-32.5
Fat (%)	19.7	31			9.0-30
Vitamin E (mg/kg)		--			27-1201a

Thiamin (mg/kg)		--			1.0-5.61a
Calcium (%)	1.14	1.3			0.29-1.01b
Phosphorus (%)	0.78	1.25			0.26-0.81b
Iron (mg/kg)		--			

Nutrient	Institution 9 L. lutra	Institution 10 L. lutra	Institution 11 L. lutra	Institution 12 L. lutra	More Carnivorous
Gross Energy (kJ/g)	23.7	19.9	23.2	25.5	
Protein (%)	57.0	63.9	58.2	51.1	19.7-32.5
Fat (%)	30.5	14.7	24.7	36.5	9.0-30
Fiber (%)	0.8	0.2	0.9	3.2	
Sodium (%)	4.2	2.4	4.5	2.4	0.05-0.4
Potassium (%)	8.0	9.3	9.9	8.3	0.4-0.6

[1] Cat NRC (2006), Legrand-Defretin & Munday (1993), Cat AAFCO (1994); Maslanka & Crissey, 1999; Mink NRC (1982); Fox NRC (1982) (for mink and fox NRC protein is range of growth and maintenance, vitamins are for growth, and minerals for growth and maintenance).

[1a] When mostly fish diets are offered, the presence of unsaturated fatty acids and thiaminases cause the breakdown of these vitamins. Thus, dietary levels of 363 mg/kg if dry diet (400 IU/kg) and 100-120 mg/kg of dry diet of thiamin are recommended.

[1b] Authors of this chapter would caution feeding diets with 0.29% calcium and 0.26% phosphorus as the Cat NRC 2006 suggests.

Lontra longicaudis diet notes:

Adult diets:

Nidasio reports that a diet originally fed adults was based on horse meat and mojarra (fish). Animals fed this diet (which offered 58% protein, 25% fat, 0.46% Ca and 1.14% P) exhibited a lower body score condition and dull coats, however. As a result changes were made following *Lontra canadensis* nutritional guidelines and resulted in improved body condition and the observation of reproduction for the first time. This new diet was based on: canned feline diet (Zupreem), hard boiled egg, pacific sierra, carrots, one day old chicks, calcium carbonate and Theralin VMP (multi-vitamin/min for cats). Crabs were offered once per week. Carrots were consumed but were not digested and removed from the diet. This diet offered 42% protein, 31% fat, 1.29% Ca, 1.25% P. Later on due to removal from the market of feline diet and theralin the diet was based on: chicken, pacific sierra, calcium carbonate, nutro (vitamin/mineral), thiamin 25 mg/kg. with day old chicks and crabs offered once a week.

Cub diets:

Diet offered to cubs weighing 1 – 4lbs. (0.453 – 1.8 kg.) was based on adult diets but offered, originally, a higher proportion of fish to chicken. It was found that the cubs ate small quantities of the high-fat fish and consumed the chicken first. As a result, the amount of chicken offered (61% chicken and 38% high-fat fish offered) was increased to maintain the desired growth rate for the cubs. Utilizing this diet the cubs consumed roughly 30% of their body weight daily instead of the more typical 20 – 25% which allowed them to maintain the desired growth rate for their age range. It is important to note again that high-fat fish should be fed. The feeding of low-fat fish resulted in lower growth rates, degeneration of body fat ratios, and possible death of cubs.

Recommendations for other species managed by the world's zoos and aquaria will be incorporated in future editions of this document.

3. NUTRIENT DESCRIPTION

Protein: Protein is the main building blocks of animal structure on a fat-free basis. In addition to being an important constituent of animal cell walls, protein is one of the nutrients responsible for making enzymes, hormones, lipoproteins, and other crucial elements needed for proper bodily functions. Protein also is essential for building and repairing body tissue, as well as protecting the animal from harmful bacteria and viruses. Furthermore, protein aids in the transportation of nutrients throughout the body and facilitates muscle contractions. The requirements for crude protein are effectively requirements for dietary amino acids. The requirements are based on the needs of the animal, the quality of the protein, the source of the protein, and the digestibility of the protein available.

Fat: Dietary fat plays an important role in the manufacture of certain hormones. It also plays a crucial role in a wide variety of chemical bodily functions. Also, fat functions as a concentrated energy source, serves as a carrier for fat-soluble vitamins (Vitamins A, D, E, and K), and provides essential fatty acids. The requirements for fat are effectively requirements for dietary fatty acids.

Vitamin A: Vitamin A is a fat-soluble vitamin essential for maintaining good vision and healthy mucous membranes. It contributes to the differentiation and growth of skin tissue and bone formation (including teeth), as well as bone remodeling in growing animals, and glycoprotein synthesis. Vitamin A can improve skin and hair/fur conditions, help to increase resistance to certain infections, and improve fertility in both genders. In many cases, a vitamin A requirement is effectively a requirement for carotenoids (precursors to vitamin A).

Vitamin C (Ascorbic Acid): Vitamin C is a water-soluble antioxidant, which plays an important role in biochemical oxidation-reduction reactions, as well as in the formation of collagen, an important protein needed for the formation of skin, scar tissue, tendons, ligaments, and blood vessels. Because of this, Vitamin C is crucial to an animal's ability to heal wounds and repair and or maintain cartilage, teeth, and bones. It also may reduce infection by increasing immunity.

Vitamin D: Vitamin D is a fat-soluble vitamin necessary for active calcium absorption, calcium metabolism and resorption from bone. Requirements for vitamin D can be totally or partially met by exposure to sunlight or artificial UV light (vitamin D is biosynthesized in the skin of animals or in some plant cells upon exposure to the appropriate wavelength of UV light; 285-315nm).

Vitamin E: Vitamin E is a fat-soluble antioxidant that helps to maintain the structure of cellular and subcellular membranes by preventing oxidation of unsaturated fatty acids. It also protects tissues from free radicals, which are substances known to harm cells, tissues, and organs. Vitamin E is essential in the formation of red blood cells and aids the body in Vitamin K utilization.

Thiamine (B-1): Thiamine is a water-soluble vitamin, which functions as a necessary coenzyme in carbohydrate metabolism (converting carbohydrates into energy) and is hypothesized to play a role in nerve or neuromuscular impulse transmission. Thiamine also is important in the proper functioning of the heart, muscles, and the nervous system.

Riboflavin (B-2): Riboflavin is a water-soluble vitamin. It functions in two coenzymes: Flavin adenine dinucleotide or "FAD" and flavin mononucleotide. Riboflavin is important for growth and the production of red blood cells. It also helps the body to release energy from carbohydrates. Microbial synthesis of riboflavin occurs in the gastrointestinal tract of some animals, but synthesis appears to be dependent on the type of animal and the source of dietary carbohydrate.

Niacin (Nicotinic Acid): Similar to Riboflavin, niacin is a water-soluble vitamin which functions in two coenzymes: Nicotinamide adenine dinucleotide or "NAD" and nicotinamide adenine dinucleotide phosphate or "NADP". Niacin plays a crucial role in assisting the normal functioning of the digestive, skin, and nerve systems. Like riboflavin, niacin helps the body to convert energy from food. The niacin requirement of many animals theoretically could be satisfied by synthesis of the vitamin from the amino acid tryptophan. However, removal rate of an intermediate in the pathway to create niacin is often so rapid that virtually none is produced.

Pyridoxine (B-6): Pyridoxine also known as B-6 is a water-soluble vitamin, which aids the body in the synthesis of antibodies by the immune system. It also plays a role in the formation of red blood cells and helps to promote healthy nerve functions. Pyridoxine is required to produce the chemical activity necessary for protein digestion.

Choline: Choline is an essential nutrient, which contributes to the function of nerve cells. It is a component (helps to form phosphatidylcholine, the primary phospholipid of cell membranes) of the phospholipid lecithin (found in cells throughout the body) and is critical to normal membrane structure and formation. It also functions as a "methyl donor", but this role can be completely replaced by excess amounts of the amino acid methionine in the diet.

Folacin (Folate, Folic Acid, B-9, Pteroylglutamic Acid): Folacin, or folate, is a water-soluble vitamin, which assists the body in the formation of red blood cells. It also plays a major role in the formation of genetic material (synthesis of DNA, the hereditary and functioning blueprint of all cells) within all living cells. Folacin functions as a coenzyme, which is important at the cellular and subcellular levels in decarboxylation, oxidation-reduction, transamination, deamination, phosphorylation, and isomerization reactions. Working in conjunction with Vitamin C and B-12, Folacin assists in digestion and protein utilization and synthesis. This vitamin may be used to increase appetite and stimulate healthy digestive acids.

Vitamin B-12: Vitamin B-12 is a water-soluble vitamin, which functions as a coenzyme in single carbon and carbohydrate metabolism. In addition to playing a role in metabolism, B-12 assists in the formation of red blood cells and aids in the maintenance of the central nervous system.
Pantothenic Acid: Pantothenic acid is a water-soluble vitamin and part of the B vitamin complex. It is needed to break down and use (metabolize) food. Pantothenic acid also is needed for the synthesis of both hormones and cholesterol.

Calcium: The mineral calcium (in association with phosphorus) is a major component of the body and is largely associated with skeletal formation. It is important in blood clotting, nerve function, acid-base balance, enzyme activation, muscle contraction, and eggshell, tooth, and bone formation and maintenance. It is one of the most important minerals required for growth, maintenance, and reproduction of vertebrates.

Phosphorus: In addition to acting as a major component of the body and being largely associated with skeletal and tooth formation (in conjunction with calcium), phosphorus is involved in almost every aspect of metabolism (energy metabolism, muscle contractions, nerve function, metabolite transport, nucleic acid structure, and carbohydrate, fat, and amino acid metabolism). Phosphorus is needed to produce ATP, which is a molecule the body uses to store energy. Working with the B vitamins, this mineral also assists the kidneys in proper functioning and helps to maintain regularity in heartbeat.

Magnesium: Magnesium is a mineral, which serves several important metabolic functions. It plays a role in the production and transport of energy. It also is important for the contraction and relaxation of muscles. Magnesium is involved in the synthesis of protein, and it assists in the functioning of certain enzymes in the body.

Potassium: Potassium is a mineral that is involved in both electrical and cellular functions in the body. (In the body it is classified as an electrolyte.) It has various roles in metabolism and body functions. Potassium assists in the regulation of the acid-base balance and water balance in blood and the body tissues. It also assists in protein synthesis from amino acids and in carbohydrate metabolism. Potassium is necessary for the building of muscle and for normal body growth, as well as proper functioning of nerve cells, in the brain and throughout the body.

Sodium (salt): Sodium is an element, which the body uses to regulate blood pressure and blood volume. Sodium also is critical for the functioning of muscles and nerves.

Iron: Iron is a trace element and is the main component of hemoglobin (oxygen carrier in the blood), myoglobin in muscles (oxygen carrier with a higher affinity for oxygen than hemoglobin), and many proteins and enzymes within the body. It also functions in immune defenses against infection.

Zinc: Zinc also is a trace element that is second only to iron in terms of concentration within the body. Zinc plays an important role in the proper functioning of the immune system in the body.

It is required for the enzyme activities necessary for cell division, cell growth, and wound healing. It plays a role in the acuity of the senses of smell and taste. Zinc also is involved in the metabolism of carbohydrates. Zinc is essential for synthesis of DNA, RNA, and proteins, and it is a component or cofactor of many enzyme systems.

Manganese: Manganese is essential for carbohydrate and lipid metabolism, for synthesis of one of the precursors to cartilage formation, and for proper bone formation. Manganese plays a key role in the growth and maintenance of tissues and cartilage, specifically proper bone development. It particularly aids in development at the ends of bones where new bone formation takes place. This therefore helps to reduce the risk of osteoporosis. Manganese also helps to produce certain hormones, metabolizes fat, and is part of superoxide dismutase (SOD) an antioxidant. Studies on humans have shown that manganese also may lower the frequency of epileptic seizures and enhance immune functioning.

Copper: Copper is an essential trace mineral present in all body tissues. Copper, along with iron, helps in the formation of red blood cells. It also helps in keeping the blood vessels, bones, and nervous and immune systems healthy.

Selenium: Selenium is an essential trace element. It is an integral part of enzymes, which are critical for the control of the numerous chemical reactions involved in brain and body functions. Selenium has a variety of functions. The main one is its role as an antioxidant in the enzyme selenium-glutathione-peroxidase. This enzyme neutralizes hydrogen peroxide, which is produced by some cell processes and would otherwise damage cell membranes. Selenium also seems to stimulate antibody formation in response to vaccines. It also may provide protection from the toxic effects of heavy metals and other substances. Selenium may assist in the synthesis of protein, in growth and development. In humans, selenium has been shown to improve the production of sperm and sperm motility.

Iodine: Iodine is a trace mineral and an essential nutrient. Iodine is essential for the normal metabolism of cells. It is a necessary nutrient for the production of thyroid hormones and normal thyroid function.

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