LION
(Panthera leo)
CARE MANUAL

CREATED BY THE
AZA LION SPECIES SURVIVAL PLAN®
IN ASSOCIATION WITH THE
AZA FELID TAXON ADVISORY GROUP

Lion (*Panthera leo*) Care Manual

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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

R. Earl

5.1 Nutritional Requirements

A formal nutrition program is recommended to meet the nutritional and behavioral needs of all species (AZA Accreditation Standard 2.6.2). Diets should be developed using the recommendations of nutritionists, the Nutrition Scientific Advisory Group (NAG) feeding guidelines:(http://www.nagonline.net/Feeding%20Guidelines/feeding_guidelines.htm), and veterinarians as well as AZA Taxon Advisory Groups (TAGs), and Species Survival Plan® (SSP) Programs. Diet formulation criteria should address the animal'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) A formal nutrition program is recommended to meet the behavioral and nutritional needs of all species and specimens within the collection.

Feeding Strategy and Foraging Behavior

The lion can be found in Africa and Asia where it is a successful predator except where in conflict with agriculture and human pressure. The lion persists mainly in open woodland, brush, scrub and grassland habitats, with additional populations found in arid, forested or mountainous regions. Lion prides defend home ranges which are size-dependent on prey and water availability and range from approximately 50 km^2 (19 mi^2) to over 700 km^2 (270 mi^2) (although with the majority of activity occurring in a central area) (Haas et al., 2005).

Lions are opportunistic predators, and acquire approximately 40% of their intake from scavenging (Haas, et al., 2005). Lions may hunt individually or as a group, with greater success in tandem. In the Kalahari, lions were successful at 40–50% of hunts, depending on prey (Eloff, 1984). Stalking time was also dependent on prey, for example 7 min (small un-preferred prey) to 30 minutes (large preferred prey) (Hayward & Kerley, 2005). Twelve to 50 kills per year are estimated per lion, depending on prey availability (Eloff, 1984).

Lions spend the majority of time (20–21 hours/day) inactive, approximately 2 hours walking and 1 hour eating, although activities may vary significantly between days. Peak activity (80–100%) occurs at night (Clarke & Berry, 1992; Eloff, 1984; Visser, 2009)

A male lion consumes a waterbuck in Sabi Sands, South Africa
H. Colahan

Lions will hunt and consume a variety of prey but the majority of kills range between 40–250 kg (88–552 lb) with an average weight of 115 kg (254 lb)/kill. If larger prey is available, lions will select for prey weighing 190–550 kg (418–1212 lb) (Hayward & Kerley, 2005). Preferred species include wildebeest (*Connochaetes taurinus*), gemsbok (*Oryx gazella*), buffalo (*Syncerus caffer*), giraffe (*Giraffa camelopardalis*), porcupine (*Hystrix africaeaustralis*) and zebra (*Equus buchelli*) (Hayward & Kerley, 2005). Similar prey preferences were found in Shamwari, where the average mass of prey killed was 132 kg (291 lb) (Rapson & Bernard, 2007) . Lions persisting in arid regions are restricted to smaller prey (average 55 kg [121 lb]; median 25 kg [55 lb]) but small prey is associated with higher cub mortality due to starvation (Eloff, 1984). Care should be taken when extrapolating prey preference to proportional contribution to the diet as availability and mass per prey species are highly variable.

When large prey is captured, lions may spend several hours consuming the kill (Visser, 2009). Kalahari lions were reported to leave on average 1/3 of the carcass (Eloff, 1984), while lions in managed settings consumed 90% of hind limbs offered and 100% of skin (Smith et al., 2006). In 4 hours of video tape on 5 kills by Masai Mara lions, only about 12% of feeding observation included bone and then only when muscle was present (van Valkenburgh, 1996). In addition to vertebrate carcass, traces of soil and grass were common in lion stomachs (Smuts, 1979).

Lions may go several days between kills either consuming and digesting large carcasses or seeking prey (Eloff, 1984). In Namibia, lions were observed to eat every 2.5 days on average (Clarke & Berry, 1992), another population was reported to average one kill every 4 days (range 1–13 days) (Smuts, 1979) and a group of Kalahari lions was reported to go as long as 8 days without a kill (Eloff, 1984). Others report lions eating every 1.5 to 3.5 days, depending on prey availability (Altman et al., 2005). Of 257 stomachs of free-ranging lions, 47.1% were found empty (Smuts, 1979).

Lions require 50 ml water/kg BW/day and acquire 50–100% of this through prey depending upon availability (Clarke & Berry, 1992; Green et al., 1984b).

Digestive System Morphology and Physiology

Lions are obligate carnivores and therefore possess a simple digestive tract comparable to the system of other carnivores (Fig. 2) (Mazak, 1981; Seymour, 1989). Dentition of the lion is reduced, with incisors and canines primarily used to bite and consume soft tissue and premolars and carnassials to slice skin and chew muscle from bone (van Valkenburgh, 1996). Pulling motions of the neck are used approximately 50% of the time and paws approximately 30% of the time when extracting food from the carcass (van Valkenburgh, 1996).

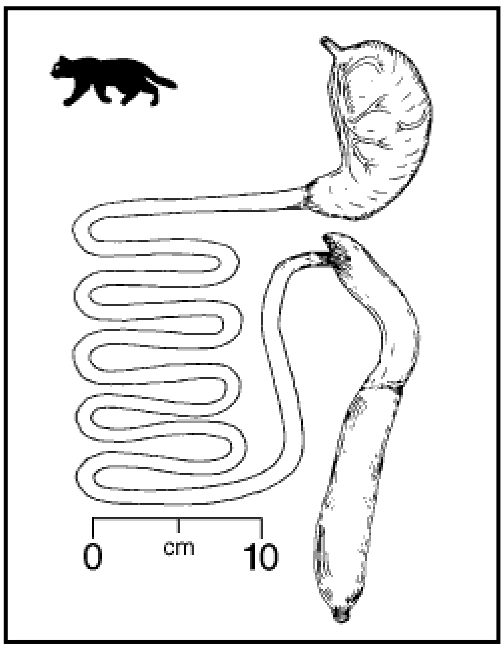


Figure 2 Digestive tract of *Felis domesticus* (Stevens & Hume, 1995). Available online from http://www.cnsweb.org/digestvertebrates/AAAEdStevensINTRODUCTION.html, accessed March 2011.

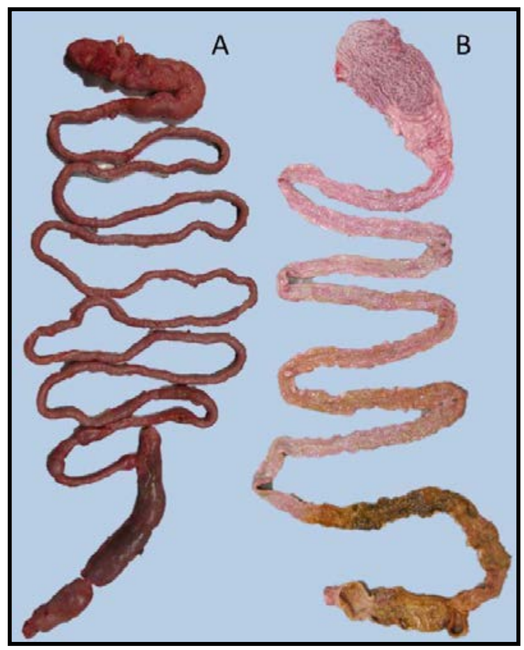


Figure 3 Digestive tract of adult female lion (115 kg) whole (A) and opened lengthwise (B) from stomach, through small intestine, cecum, large intestine and rectum. Total intestine length was 344 cm, which was significantly shorter than the average length of 3 other lions measured (746 cm) (Smith et al., 2006). The stricture in the lower large intestine shown here was not reported for other lions, tigers, or domestic cats and is expected to be abnormal.

The esophagus of the lion is approximately 70–80 cm (28–31 in.) long (Smith et al., 2006). The stomach can hold a substantial volume (20% of BW or greater) (Eloff, 1984). Measured stomach contents great than 20% BW were found to be common in cubs, but usually below 15% in adult lions (Smuts, 1979).

The small intestine comprises 74% of the total gastrointestinal tract length at 6–7 m (19–23 ft) (Smith, et al., 2006). A small cecum (approximately 10 cm [4 in.] or 1% of tract) is present at the intersection between small and large intestine. The large intestine is just over 1 m (3 ft) in length (13% of tract) (Smith et al., 2006). These values are comparable, proportionally, to reported values in tigers (*Panthera tigris*) and one jaguar (*Panthera onca*) (Mazak, 1981; Seymour, 1989) with both species also possessing small ceca. The intestine of domestic cats (*Felis domesticus*) maintains bacterial colonies comparable to those in herbivorous species (Brosey et al., 2000) which can provide protection against invading bacteria, stimulate gastrointestinal function such as immunity and motility and digest fiber sources to produce volatile fatty acids (Suchodolski, 2011). This is likely for *Panthera leo* as well, however due to the small relative volume of the feline tract, the contribution to digestion is probably negligible (Suchodolski, 2011).

This digestive tract allows for storage of large meals in the stomach and efficient digestion of vertebrate prey (Bennett et al., 2010; Clauss et al., 2010; Smith et al., 2006; Vester et al., 2010) but limited digestion of more complex fiber sources which omnivores and herbivores are able to utilize (Edwards et al., 2001; Wynne, 1989).

Energy Requirements

Equations for basal metabolic rates (BMR) in carnivores are higher than for omnivorous or herbivorous species with predicted daily energy requirements of 50-75 kcal/kg $BW^{0.75}$/day for lions and domestic cats (McNab, 2000, 2008; Munoz-Garcia & Williams, 2005). Examples of 52 managed lion diets provided approximately 130 kcal/kg $BW^{0.75}$, 1.7–2.5 times the expected BMR (Table 5). This is higher than the daily maintenance energy requirement predicted for domestic cats at maintenance (90 kcal ME/kg$BW^{0.75}$) which is only 1.5 time BMR (NRC, 2006). The estimated field metabolic rates (FMR) for carnivores the size of lions are 4–6 times BMR (Nagy et al., 1999), around 2.5 times higher than the energy level provided by diets in zoos. Field metabolic rates calculated for domestic cats are also 2.5 times the expected maintenance requirement (Nagy et al., 1999; NRC, 2006) Lower energy requirements for zoos lions and domestic cats likely reflect reduced activity associated with hunting and territory defense.

Estimates of food and energy intake in adult wild lions averaged 195 kcal/kg $BW^{0.75}$/day, falling between the energy requirements of zoo lions and estimates of FMR for carnivores. High metabolic rates in carnivores are attributable to high cost of capturing and handling food which may be partially ameliorated by the social behavior of lions.

Based on these observations, a maintenance requirement of 115–130 kcal/kg$BW^{0.75}$ for lions in zoos is proposed (approximately 3.5 kg [7.8 lb] per day for adult male lions and 2.7 kg [6 lb] per day for adult female lions) based on diets containing 1.75 kcal/g. Individual feeding rates should be evaluated and readjusted based on regular assessment of body condition score and weights.

Table 5: Estimates of daily energy and prey requirements for lions (*Panthera leo*). Zoo diets (reported as mean and range) are based on values and schedules reported by AZA institutions and may fail to account for whole prey or bones. Calculations based on 1.75 kcal ME/g for zoo raw diets and 1.4 kcal ME/g wild diet based on previous estimates and whole prey values (Bennett, et al., 2010; Green, et al., 1984; Smith, et al., 2006). If bodyweights were not reported, 185 kg (407 lb) was used for adult males, 130 kg (286 lb) for adult females, and 150 kg (330 lb) for unspecified adults.

Lion	BW (kg)	kg/d	kcal/d	kcal/kg $BW^{0.75}$/d	Reference
BMR male[e]	185		2500–3770	50–75	(McNab, 2000, 2008; Munoz-Garcia & Williams, 2005)
BMR female[e]	130		2000–2820	52–73	(McNab, 2000, 2008; Munoz-Garcia & Williams, 2005)
Zoo male (n=23)		3747 (2330–6031)	6558 (4077–10555)	131 (81–210)	
Zoo Female (n=21)		2502 (1750–3772)	4379 (3063–6602)	114 (80–171)	
Zoo unspecified (n=8)		3247 (2273–4286)	5683 (3977–7500)	133 (53–175)	
Male	193	5060 [c]	7084	137	(Green et al., 1984)
Adult		4930[a]	6902	161	(Green et al., 1984)
Adult		5100[a]	7140	167	(Green et al., 1984)
Female		4700[a]	6580	171	(Eloff, 1984)
Female		5000[a]	7000	182	(Schaller, 1976)
Male		7000[a]	9800	195	(Schaller, 1976)
Male		7200[a]	10080	201	(Eloff, 1984)
Female (n=3)	139.5	6090 ±2000[c]	8526	210	(Green et al., 1984)
Female[b]		6700[a]	9380	244	(Rapson & Bernard, 2007)
Male[b]		10050[a]	14070	280	(Rapson & Bernard, 2007)
FMR male[d]	185		15069	300	(Nagy et al., 1999)
FMR female[d]	130		11090	288	(Nagy et al., 1999)
Male cub	91	6530 [c]	9142	310	(Green et al., 1984)

Felis domesticus	BW (kg)	kg/d	kcal/d	kcal/kg $BW^{0.75}$/d	Reference
BMR	4			56–64	(McNab, 2000, 2008; Munoz-Garcia & Williams, 2005)
FMR	4			190–217	(Nagy et al., 1999)
Maintenance	4			90	(NRC, 2006)
Gestation	4			125–140	(NRC, 1986, 2006)
Peak Lactation	4			208	(NRC, 2006)

[a]Diet estimated from observed kills
[b]Female equivalent is the amount estimated per female lion based on observations of multiple lion groups. An adult male lion was estimated to represent 1.5 FEQ
[c]Diet estimated from sodium turnover
[d]Field metabolic rate derived from 7 species of Carnivora
[e]Basal metabolic rates derived from estimates for Carnivores, Carnivora, and Felidae with highest values estimated from 12 species of Felidae including 1 subadult lion.

Reproduction
Gestation and lactation in the domestic cat are periods of increased energy demand. The maternal contribution to reproduction is dependent on the size of the litter, growth rate of the offspring, and relative size of the offspring; therefore comparison between the domestic cat and larger felids may not be appropriate. Energy requirements for the domestic cat are approximately 40% higher during gestation and approximately twice that of maintenance during peak lactation (NRC, 2006), however no difference in metabolic rate was observed in a female puma (*Puma concolor*) during lactation (McNab, 2000). A factorial approach might allow for the most appropriate extrapolation of energy requirements (ME_{lact}) for exotic felids (E. Kienzle, 1998):

$$ME_{lact}\ kcal/d = ME_{mat} + [\%N*(ME_o + ME_{og})]/Efficiency_{milk}$$

Where $Efficiency_{milk}$ is the conversion factor for maternal ME intake to milk ME output, which has been assumed to be 70% in cats (Kienzle, 1998). %N is the proportion of the offspring's energy derived from nursing (as opposed to solids), ME_o is the maintenance energy requirement for the offspring and ME_{og} is the energy for offspring growth. Using milk output and intake studies (Hendricks & Wamberg, 2000b; Kienzle, 1998) and energy estimated for lion maintenance and growth presented elsewhere in this chapter, the above equation becomes:

$$ME_{lact}\ kcal/d = 125*BW_m^{0.75} + [\%N*(125*\Sigma(BW_o^{0.75}) + 1.8(ADG_o))]/0.7$$

Where BW_m = maternal bodyweight, kg; BW_o = weight of each offspring, kg; and ADG_o = combined g growth of offspring.

During gestation the female domestic cat gains mass in addition to the mass of the kittens then subsequently loses weight during lactation (NRC, 2006). Optimal weight gain or weight loss during reproduction in large felids has not been studied. Since extreme body condition scores are associated with multiple health risks to the mother and offspring, it is recommended that gestating and lactating lionesses be fed to maintain body condition within the moderate range (BCS 4-6).

Growth
Energy requirements for post-weaning growth in domestic cats are estimated as:

$$ME_g\ kcal/d = ME_m \times 6.7\times [e^{-0.189p}-0.66]$$

Where ME_m = maintenance energy requirement and p = proportion of mature bodyweight = bodyweight/mature bodyweight. Example expected values for p are reported in Table 6. This equation can be estimated by the linear equation:

$$ME_g\ kcal/d = ME_m + (1.3*ME_m -1.15*p)$$

Such that as p approaches 0 (birth), ME_g approaches 2.3*Maintenance and as p approaches 1 (maturity), ME_g approaches $1.13*ME_m$ (i.e. overestimates energy requirements close to maturity by 13%). An alternative equation based on energy requirements derived from nursing kittens for which 1 g gain costs 1.8 kcal (Hendricks & Wamberg, 2000; E. Kienzle, 1998) is:

$$ME_g\ kcal/d = ME_m + 1.8(ADG)$$

These equations were fit to growth and hand-rearing data for three lion cubs using 125*BW$^{0.75}$as the maintenance energy requirement, 130 kg (286 lb) as mature bodyweight, and the broken-line model for average daily gain (ADG). The NRC equation overestimated kcal consumed by 50% (interquartile range +32% to +69%). The Hendricks equation underestimated kcal consumed by 6% (interquartile range -18% to +17%) so would appear to be a better estimator of energy requirement for lion growth. However this equation and the growth curves presented below only represent a guideline. Lion cubs should be monitored with regular weights and visual assessment to determine appropriate individual feeding rates.

Weight data were collated from 190.229 parent reared, 74.73 hand reared, 33.32 unknown reared, and 23.25 wild born African lions reported in the literature (Clarke & Berry, 1992; Green et al., 1984; Haas et al., 2005; Schaller, 1976; Smuts et al., 1980; Visser, 2009) and 27.43 parent reared, 8.19 hand reared, and 1.2 unknown reared Asian lions for a total of 779 lions and 14,456 data points. Weights of male lions were always greater than female lions of the same age, but there was no difference between Asian and African lions nor was there a difference between parent-reared lions in human care which were wild born versus zoo-born. Data were compared to growth curves for 158.186 wild lions reported in the literature (Smuts et al., 1980) (Figure 4, Figure 5, Table 6).

Growth is often assumed to be linear in young animals, including domestic cats and as was reported in wild lions (Smuts et al., 1980) and in general this is an adequate assumption. However, when assessing the needs of neonates (for example when hand-rearing) a more accurate model of early growth is critical. Unfortunately continuous growth curves for lion in human care and wild lions fail to estimate reasonable weights during the first year of growth (Smuts et al., 1980). The broken-line model was constrained to derive accurate weight estimates from birth to maturity to provide a practical tool for evaluation of growing lions.

The rate of lion growth differed based on rearing and gender, however changes in the growth rate (breakpoints) were similar for males and females within each rearing group. Parent-reared males and females accelerated growth around 45 and 100 days of age whereas hand-reared males and females began growing at about 72% of the parent-reared rate but accelerated earlier around 30 and 70 days of age so that they equaled or surpassed the parent-reared animals in weight around 85 days of age. All animals decelerated growth around 18 months of age and reached mature weights around 3 years of age. After 365 days of age, the broken-line and continuous growth curve become similar and both could be appropriate (Zullinger et al., 1984). Continuous deceleration of growth is more physiologically accurate; however the broken-line model also describes the data well.

Continuous growth curves for both wild and zoo animals predicted maximum average daily gains around 10 months for female lions and 11 months for male lions (Smuts et al., 1980), however maximum growth rates for wild lions were predicted to be only 60% of the maximum rate for lions in human care. Overall, wild lions grew more slowly and for a longer period of time, although the linear estimate of growth predicted maturity at a similar age to lions in human care (Smuts et al., 1980). The difference between these animals was also observed by Smuts et al. (1980) and attributed to restricted nutrient availability for wild lions. This suggests that the higher growth rates in zoo animals reflect a more optimal plane of nutrition. Conversely, too-rapid growth rates can increase the risk of metabolic disorders, particularly in association with obesity. Rapid “catch-up”’ growth following periods of restriction may exacerbate these risks and could be occurring in hand-reared animals (Forsen et al., 2000; Ozanne, 2001; Ozanne & Hales, 2005). However, due to the small differences between hand-reared and parent-reared lions, the likelihood that nutrition is limiting in wild lion populations, limited data suggesting that metabolic disease is a significant problem in lions in human care, the growth rates reported here for both parent-reared and hand-reared lions in human care are expected to be appropriate. Difference in growth rate of hand-reared animals may result from formula composition initially followed by more rapid weaning to solids.

Figure 4. Growth curves of male lions in human care plotted with models from 158 wild lions (Smuts et al., 1980).

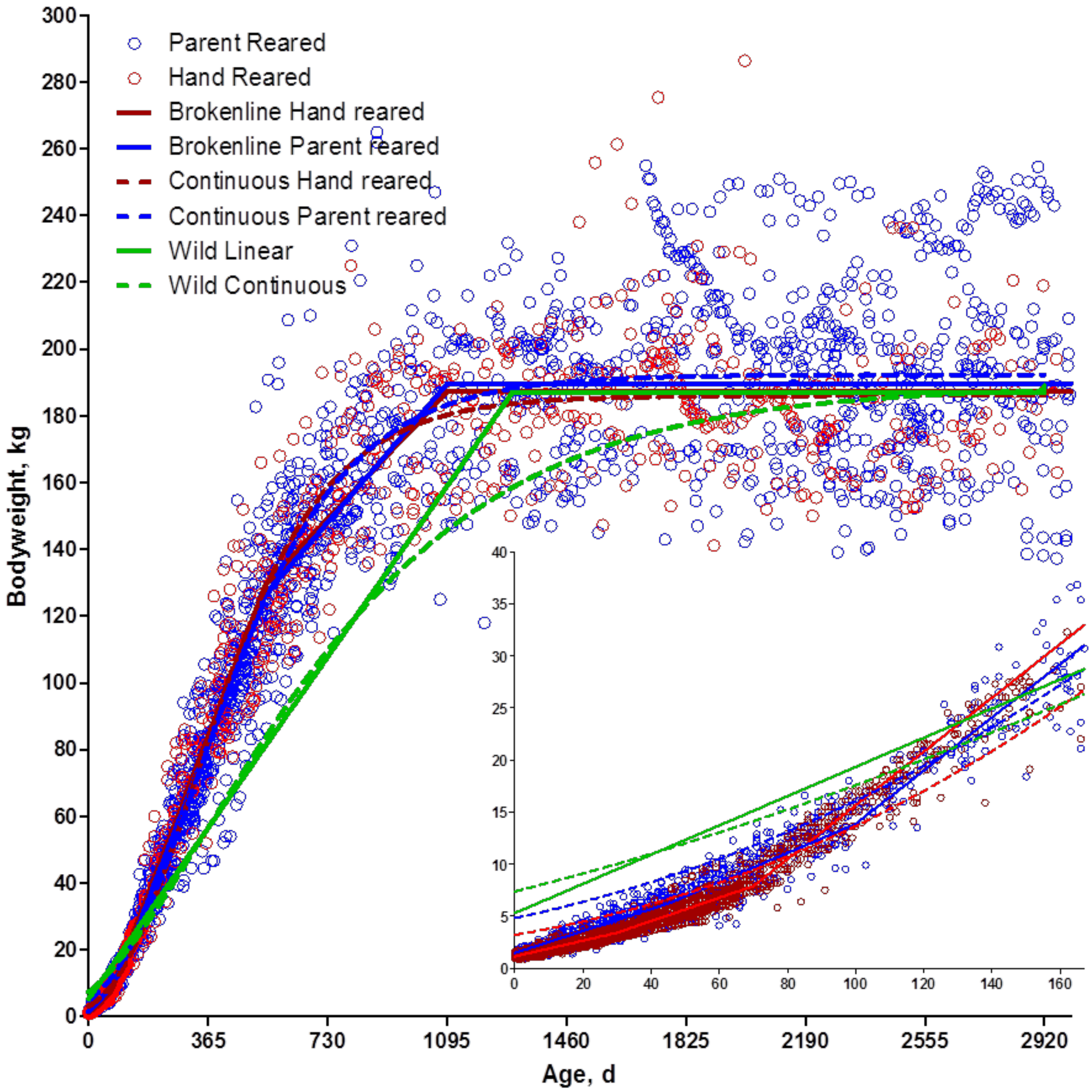


Figure 5. Growth curves of female lions in human care plotted with models from 186 wild lions (Smuts et al., 1980).

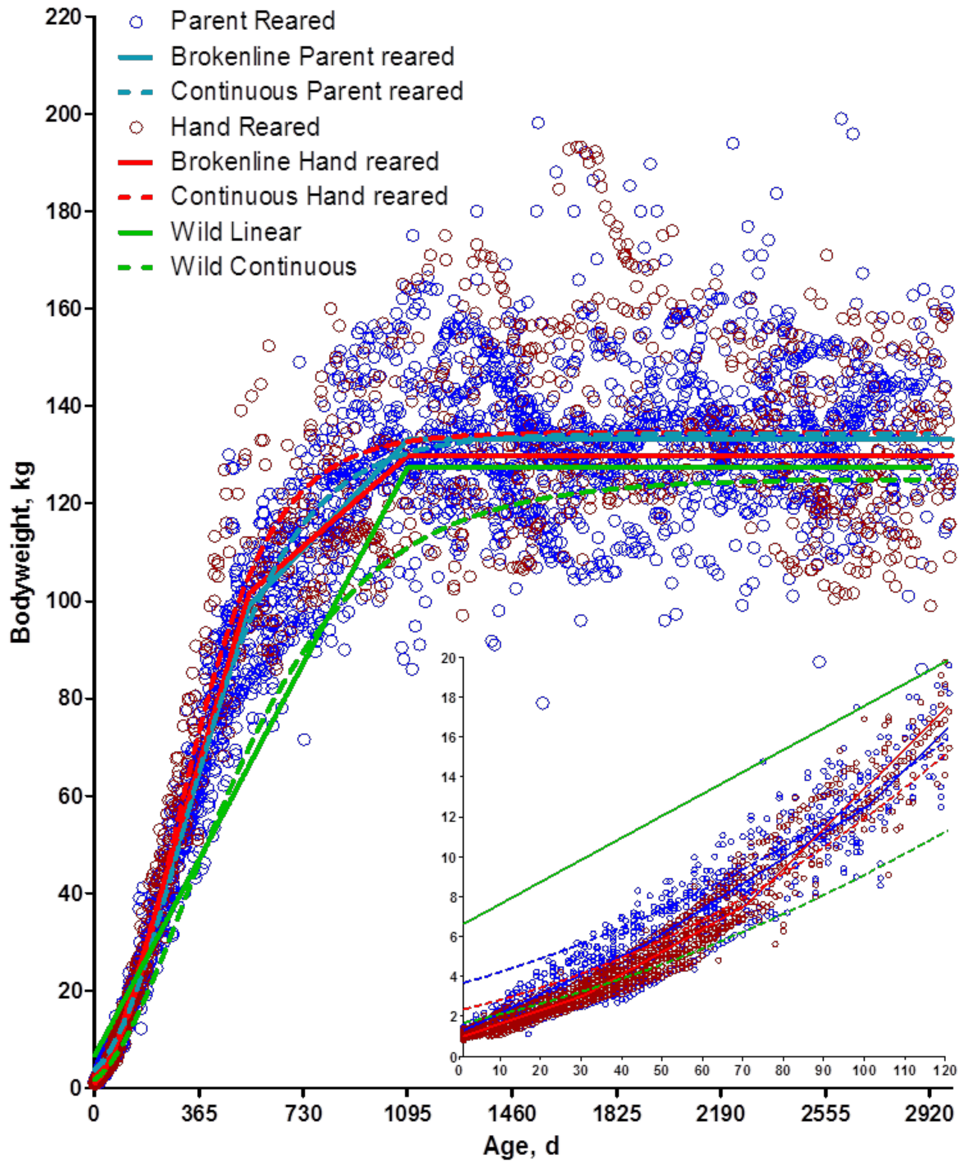


Table 6. Growth Curves for lions in zoos and wild lions reported by Smuts et al. (1980). Observed birth weights were 1.5 ± 0.2 and 1.2 ± 0.2 kg for male parent- and hand-reared lions in zoos and 1.3 ± 0.2 and 1.1 ± 0.2 for female parent- and hand-reared lions in zoos, respectively. Observed mature weights were 192 ± 22 and 187 ± 22 kg for male parent- and hand-reared lions in zoos and 134 ± 17 and 135 ± 18 kg for female parent- and hand-reared lions in zoos, respectively.

Male lions	**In Zoos**				**Wild**	
	Broken line		Continuous[6]			Linear
Rearing	Parent (n=218)	Hand (n=60)	Parent (n=218)	Hand (n=60)	Wild (n=158)	Wild (n=158)
Birthweight[3], kg	1.5	1.3	4.9	3.2	7.5	5.4
Mature weight, kg	190	187	192	186	188	NA
Time to maturity[4], d	1062	1060	1313	1197	2250	1267
Time to 50% maturity, d	417	402	422	400	610	629
Max ADG, g/d	256	258	280	303	159	140
Age of max ADG, d	100–540	70–540	329	317	361	0–1095
	Average daily gain[5], g/d					
0–30	105	76	70–94	57–81	82–95	140
30–45		112	94–107	81–98	95–101	
45–70	139		107–130	98–124	101–110	
70–100		258	130–158	124–158	110–121	
100–365	256		158–280	158–303	121–159	
365–540			278–214	297–211	159–148	
540–730	114	104	214–127	211–113	148–124	
730–1095			127–35	113–25	124–75	
1095–1460	0	0	35–9	25–5	75–41	NA
Female	**In Zoos**				**Wild**	
	Broken line		Continuous[6]			Linear
Rearing	Parent (n=272)	Hand (n=83)	Parent (n=272)	Hand (n=83)	Wild (n=186)	Wild (n=186)
Birthweight[3], kg	1.2	1.0	3.7	2.4	1.7	6.7
Mature weight, kg	133	130	134	135	125	127
Time to maturity[4], d	1052	1044	1188	1024	1729	1071
Time to 50% maturity, d	375	357	378	341	482	517
Max ADG, g/d	197	200	216	256	151	110
Age of max ADG, d	100-540	70-540	293	270	304	0-1095
	Average daily gain, g/d[4]					
0–30	96	69	58–79	49–74	44–64	110
30–45		113	79–90	74–90	64–73	
45–70	127		90–110	90–117	73–88	
70–100		200	110–133	117–151	88–104	
100–365	197		133–216	151–256	104–151	
365–540			207–142	231–135	148–122	
540–730	61	51	142–75	135–59	122–86	
730–1095			75–17	59–10	86–37	
1095–1460	0	0	17–4	10–1	37–14	NA

Energy of feeds

Several equations for estimating the energy content of typical cats feeds are available (Clauss et al., 2010; NRC, 2006) as well as numerous papers determining gross energy and digestible energy (Barbiers et al., 1982; Bennett et al., 2010; Vester et al., 2010). Care should be taken when making, comparing or reporting estimates that the different terms for energy are used appropriately (i.e. gross energy (GE) * digestibility = digestible energy (DE) * metabolic efficiency = metabolizable energy (ME)). A review of literature on raw diets and whole prey as are generally offered to lions in zoos supported the following Atwater equation for estimating ME in carnivores (Clauss et al., 2010):

$$\text{ME kcal/kg} = 39.9*(\%CP+\%NFE) + 90.0*(\%Fat)$$

Where %CP is the percent crude protein and %NFE is the percent nitrogen free extract (which can be estimated as 100-CP-Fat-Fiber-Ash.

The more specific an estimation equation is to the feed evaluated, the more accurate the estimate, therefore estimates based on a single property (e.g. protein or fiber) should be used with caution. Feed composition varies between products, manufacturers and even lots (Allen et al., 1995) therefore regular quality control of feeds and assessment of managed animals for changes in weight or condition remain critical.

Nutrient Requirements
The nutrient content of food items consumed by lions has not been completely characterized. For the limited number of nutrients studied, the domestic cat remains an appropriate model (Vester et al., 2010). The nutrient levels presented below have been recommended by the National Research Council of the National Academies for the domestic cat (Table 7). As in all species, nutrient requirements vary depending on growth, activity, reproductive status, health status, environment and group dynamics.

Table 7. Target nutrient levels for carnivores on a dry matter basis (NRC, 2006).

Nutrient	Growth	Maintenance	Gestation/Lactation	All
Protein, %	22.5	20.00	21.3-30.0	20.0–30.0
Fat, %	9.00	9.00	15.00	9.0–15.0
Linoleic acid, %	0.55	0.55	0.55	0.55
Vitamin A, IU/g	3.55	3.55	7.50	3.55–7.50
Vitamin D3, IU/g	0.25	0.25	0.25	0.25
Vitamin E, mg/kg	38.00	38.00	38.00	38.00
Vitamin K, mg/kg	1.00	1.00	1.00	1.00
Thiamin, ppm	5.50	5.60	5.50	5.5–5.6
Riboflavin, ppm	4.25	4.25	4.25	4.25
Niacin, ppm	42.50	42.50	42.50	45.50
Vitamin B6, ppm	2.50	2.50	2.50	2.50
Folic acid, ppm	0.75	0.75	0.75	0.75
Biotin, ppm	0.08	0.08	0.08	0.08
Vitamin B12, ppm	0.02	0.02	0.02	0.02
Pantothenic acid, ppm	6.25	6.25	6.25	6.25
Choline, ppm	2550.00	2550.00	2550.00	2550.00
Calcium, %	0.80	0.29[1]	1.08	0.29–1.08[1]
Phosphorus, %	0.72	0.26[1]	0.76	0.26–0.72[1]
Magnesium, %	0.04	0.04	0.06	0.04–0.06
Potassium, %	0.40	0.52	0.52	0.40–0.52
Sodium, %	0.14	0.07	0.13	0.07–0.14
Iron, ppm	80.00	80.00	80.00	80.00
Zinc, ppm	75.00	75.00	60.00	60–75
Copper, ppm	8.40	5.00	8.80	5.0–8.8
Manganese, ppm	4.80	4.80	7.20	4.8–7.2
Iodine, ppm	2.20	2.20	2.20	2.20
Selenium, ppm	0.40	0.40	0.40	0.40

[1]Data do not exist for large maintenance level exotic felids fed 0.3% calcium and phosphorus diets.

As obligate carnivores, lions have unique nutrient requirements compared to omnivores. These differences are consistent with constant consumption of a high protein diet. Strict carnivores require higher levels of most essential amino acids, taurine, preformed vitamin A, niacin, and arachidonic acid (NRC, 1986). Omnivores can meet these requirements with other nutrients or possess enzymes or greater enzyme activity to up-regulate metabolic pathways to meet these requirements.

5.2 Diets

The formulation, preparation, and delivery of all diets must be of a quality and quantity suitable to meet the animal's psychological and behavioral needs (AZA Accreditation Standard 2.6.3). Food should be purchased from reliable, sustainable and well-managed sources. The nutritional analysis 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.

Food preparation must be performed in accordance with all relevant federal, state, or local regulations (AZA Accreditation Standard 2.6.1). Meat processed on site must be processed following all USDA standards. 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.

AZA Accreditation Standard

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

Diet Composition

Lions in zoos can be maintained on diets consisting of commercially available meat mixes, whole prey, bones, carcasses, and muscle meat diets balanced with supplements. Some or all of these ingredients fed in combination should meet the target nutrient ranges for domestic cats (Table 7).

Commercially prepared meat mixes should be formulated to meet the nutrient needs specific to cats. As such, these products have the advantage of requiring no additional supplementation. However, soft diets provide little abrasion for good dental health and thus should be fed with whole prey, bones or carcass. Meat mixes have traditionally consisted of predominately horse or beef. More recently, pork products have become available (Watts, 2011). In general, these diets are well digested by lions. Studies comparing digestibility of horse and beef diets fed to large cats (lion, cheetah, tiger, jaguar) and domestic cats show high digestibility of dry matter (75–90%), organic matter (79–96%), crude protein (81–97%), and fat (92–97%) with variability attributable to level and type of fiber, collagen content, ingredients and possibly species (Barbiers, et al., 1982; Morris, et al., 1974; Vester, et al., 2010; Wynne, 1989). Domestic cats fed the same diets had similar or greater nutrient digestibilities further supporting the cat as an appropriate model for exotic carnivores.

Commercial meat mixes contain little fiber (3% max, dry matter basis) with sources typically either cellulose or beet pulp. Cellulose is considered unfermentable and beet pulp moderately fermentable. Fermentable fiber has been suggested to promote intestinal health in domestic cats by supporting intestinal cells and microflora (Barry, et al., 2010). Small exotic felids (leopard cat, caracal) have been maintained on diets including fructooligosaccharides, another fermentable carbohydrate (Edwards et al., 2001)

All products, regardless of meat and fiber source should meet the target nutrient ranges discussed above. Additionally, products should meet the below ingredient standards (Allen et al., 1999).

Ingredient and Product Standards

All meat and meat products shall originate from animals slaughtered in plants subject to the Meat and Poultry Inspection Operations regulations of the USDA Food Safety and Inspection Service (FSIS), or under a system of inspection approved by FSIS. All bones, cartilage, heavy connective tissue, lymph glands, and central nervous system tissue shall be removed. Likewise, meat and meat products that originate from animals or carcasses designated as 3-D or 4-D shall not be used. Other (non-meat) ingredients shall conform to standards as defined by the Association of Feed Control Officials (AAFCO). The product shall be routinely monitored for specific microbial populations. The diet must test negative for the presence of *Salmonella* and *Listeria*, and within specified tolerance limits for total coliforms and *E. coli*.

Bones are recommended for abrasion for dental health and for enrichment, provided abnormal deleterious wear does not occur such as loss of enamel or damage to the teeth (Briggs & Scheels, 2005). Twice weekly feeding may favor more frequent plaque dislodgement and markedly reduced calculus formation and gingivitis (Haberstroh et al., 1983). Bones commonly fed to lions include: horse neck bones, horse tails, oxtails, knuckle bones, and femurs. Ribs bones are less common.

Whole prey is an intact animal with entrails and fur (or feathers) typically chicks, quail, rabbits, rats, and mice. Whole prey is also recommended to ensure proper dental health. The hide/fur, cartilage, gut and gut contents more approximate the natural diet of lions than hard bones and may therefore be more appropriate for abrasion. Whole prey fed to lions includes predominately rabbits but also guinea pigs, and rats.

The diet of wild lions is whole carcass. In zoos, whole carcass may or may not have the hide and viscera removed. Carcass typically refers to larger animals such as goats, sheep, calves, and deer. *Ex situ* supplementation of whole carcasses can promote a wide range of feeding and foraging behaviors. Institutions choosing to feed carcass should be aware potential hazards that may exist including presence of pharmaceutical drugs, pesticides, toxic organic compounds, pathogenic bacteria (Harrison et al., 2006). The origin and history of the carcass should be known and institutions must follow USDA policy #25 (USDA, 1998) specifying feeding the carcass as soon as possible or processing into smaller pieces and freezing, avoiding sick animals, removing lead shot from animals euthanized by gunshot, avoiding animals with signs of central nervous system disease or at risk of transmissible spongiform encephalopathies, including animals with scrapie, chronic wasting disease, and those with Johne's disease. Feeding of roadkill is discouraged. The AZA Nutrition Advisory Group only condones carcass feeding as part of a feeding program that ensures the diet of the animal is nutritionally balanced and free of pathogens. Whole carcass fed to lions includes deer, goats, sheep, whole or quartered, turkeys and chickens. See Chapter 8 for more information on food enrichment.

Muscle meat does not provide a complete diet. Muscle contains too little calcium, vitamins A, D, and E and other micronutrients to support health without additional sources of these nutrients. Muscle meat can be fed in combination with other diet items that meet the target nutrient levels so that additional supplementation is not required. For example, muscle meat is often utilized as a training tool or a medication vector. If muscle meat must be fed at a significant level in the diet or exclusively, the following supplementation is recommended per 2 kg of muscle (Ullrey & Bernard, 1989):
5 g calcium carbonate
10 g dicalcium phosphate
1.5 g (1 tablet) Centrum multi vitamin mineral tablets

Commercially available supplements specifically designed to balance muscle meat, such as Mazuri Carnivore supplement and Nebraska Meat Complete with Taurine, can also be fed.

Enrichment foods consumed by lions should be considered a part of the diet. All dietary enrichment should go through an institutional approval process, including review by nutritionists and veterinarians. All new items should be monitored closely when first provided. Ice should be used with caution considering several cases of tooth damage in domestic and exotic carnivores treated by zoo dentists (Briggs & Scheels, 2005).

Standards for inspecting meat and whole prey items are available in the *USDA Manual of Standard Operating Procedures for Handling Frozen/Thawed Meat and Prey Items Fed to Captive Exotic Animals* (Crissey et al., 2001). Food items from non-domestic stock should be frozen prior to feeding to kill any pathogens that might be present. Meat-based diets should not be allowed to warm to room temperatures or above for extended periods of time, as this may result in the growth of harmful bacterial organisms.

Sample Diets
Those institutions supplying detailed diet information fed diets based on commercially available nutritionally complete meat mixes using beef, horse, or pork (Table 8). Though carcass was not fed in the below diets, from a general survey, AZA institutions do feed carcass.

Table 8. Ingredient composition as a percent of the total diet (as fed) of 24 diets offered at 8 institutions

Ingredient	Average	Range
Meat mix[1]	75%	59–91%
Whole prey[2]	5%	0–12%
Bones[3]	15%	6–32%
Chunk meat[4]	5%	0–14%

[1]Meat mixes: Natural Balance Carnivore 5, Natural Balance Carnivore 10, Natural Balance Pet Foods, Pacoima, CA; Nebraska Premium Feline and Canine diets, Nebraska Premium Beef Feline, Nebraska Premium Beef Feline, 10%, Nebraska Special Beef Feline, Central Nebraska Packing, Inc. North Platte, NE; Toronto Zoo Feline Diet, Milliken Meat Products, Ltd., Markham, Ontario, Canada; Tucker's Zoological Select.
[2]Whole prey: rabbits, guinea pig
[3]Bones: Horse or beef femur or knuckle bones, horse necks, beef ribs, horse tails
[4]Chunk meat: horse muscle meat, beef heart, chicken breast.

Table 9. Nutrient content, energy on an as fed basis, all other nutrients on a dry matter basis, of 20 sample diets compared to target nutrient levels described in Table 7.

Nutrient	Average	Range	Target Range[1]
Energy, kcal/g AS FED	1.77	1.35–2.09	-
Protein, %	55.18	48.53–60.56	20.0–30.0
Fat, %	28.59	19.44–39.50	9.0–15.0
Ash, %	7.22	5.14–9.34	NA[2]
Linoleic acid, %	NA[3]	NA[3]	0.55
Vitamin A, IU/g	11.45	10.31–14.22	3.55–7.50
Vitamin D3, IU/g	NA [3]	NA[3]	0.25
Vitamin E, mg/kg	365.07	276.8–418.4	38
Vitamin K, mg/kg	NA [3]	NA [3]	1
Thiamin, ppm	11.06	9.16–12.28	5.5–5.6
Riboflavin, ppm	14.20	11.11–16.09	4.25
Niacin, ppm	163.44	128.0–282.20	45.5
Vitamin B6, ppm	17.76	12.51–20.39	2.5
Folic acid, ppm	0.86	0.26–1.42	0.75
Biotin, ppm	NA[3]	NA[3]	0.08
Vitamin B12, ppm	0.10	0.07–0.16	0.02
Pantothenic acid, ppm	NA[3]	NA[3]	6.25
Choline, ppm	NA[3]	NA[3]	2550
Calcium, %	1.89	1.45–2.14	0.29–1.08
Phosphorus, %	1.45	0.91–1.59	0.26–0.72
Magnesium, %	0.11	0.10–0.12	0.04–0.06
Potassium, %	0.89	0.40–1.06	0.40–0.52
Sodium, %	0.56	0.40–0.96	0.07–0.14
Iron, ppm	172.92	139.60–197.30	80
Zinc, ppm	116.39	98.3–199.90	60–75
Copper, ppm	13.18	8.61–21.16	5.0–8.8
Manganese, ppm	19.77	10.99–26.19	4.8–7.2
Iodine, ppm	NA[3]	NA[3]	2.2
Selenium, ppm	0.53	0.23–0.67	0.4

[1]Target nutrient range encompassing growth, pregnancy, lactation, and maintenance from table 7.
[2]Nutrient requirement not established.
[3]Missing values in database thus composition could not be calculated.

Feeding Schedules

Food items are either fed daily or rotated throughout the week.

Table 10. Example of a possible feeding schedule for lions

Ingredient	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Meat mix	X	X		X	X	X	
Guinea pig			X				
Rabbit							X
Knucklebone							X
Horse tail			X				
Chunk meat	X	X	X	X	X	X	X

Fasting for 24 hours without access to food is part of the feeding management at some institutions. Per USDA #25 animals should not be fasted more than 2 days per week.

Overall, most diets as reported would meet the known nutrient requires for cats for all physiological stages.

Provision of water
Clean, potable drinking water should be available at all times. Regardless of size, portable water containers should be cleaned and disinfected daily; built-in streams and pools should be cleaned and disinfected at least weekly. In cold climates, installation of means to prevent pipes freezing is an important consideration.

In outdoor exhibits or large indoor enclosures, water features for drinking, bathing, and aesthetics can be added in the form of pools, re-circulating streams, large, built-in water features, or commercial livestock waterers. As lions routinely defecate in pools, auxiliary drinking water sources should be provided. All water features should be drained, cleaned, and sanitized on a regular basis. See Chapter 1 for more information on types of drinkers and water features.

5.3 Nutritional Evaluations

Nutrition-Related Health Issues
Thiamine Deficiency: A case was reported of a young lion with presumed primary thiamine deficiency due to a diet of only beef muscle meat. Clinical signs observed included ataxia, generalized weakness, marked hypermetria and seizure-like episodes. Blood thiamine level in this lion was 11 nmol/L (normal reference range 160-350 nmol/L (Hoover & DiGesualdo, 2005). Signs improved with supplementation of thiamine and changing to a more balanced diet (DiGesualdo et al., 2005).

Hypovitaminosis A: Vitamin A deficiency has been reported in young lions (Hartley et al., 2005; Maratea et al, 2006; McCain et al., 2008; Shamir et al., 2008). Most cases presented with neurological signs, including ataxia, tetraparesis, seizures, head tilt, and opisthotonus. Death can occur within a few months, although affected animals are often euthanized as a result of the neurologic deterioration. The most common finding on pre-mortem or post-mortem examination is occipital bone proliferation with secondary cerebellar herniation through the foramen magnum, similar to a Chiari I-type malformation. A degenerative myelopathy of the cervical cord has been observed as well (Maratea et al., 2006). Vitamin A levels of <20 IU/g wet liver have been reported in all of these cases (normal reference value of 5,400 IU/g wet liver was obtained from a free-living lion) (Shamir et al., 2008). Milder clinical cases may respond to vitamin A supplementation. Sub-occipital craniectomy has been used with success in two reported cases (McCain et al., 2008; Shamir et al., 2008).

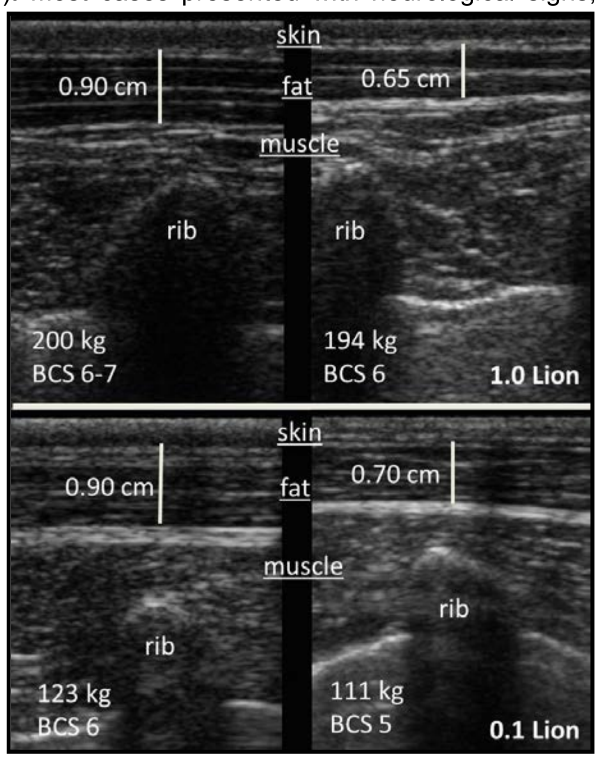


Figure 6 Transcutaneous ultrasound images over ribs of 1.1 lions during annual exams. Standardization of ultrasound location using morphometric measures is critical when comparing across images.

Body Condition Scoring
Obesity is purported to be the most common nutritional disorder in domestic felines (Zoran, 2002). The most practical method for evaluating degree of fatness for animals which cannot be readily palpated is visual body condition scoring. Body condition scoring (BCS) systems provide a spectrum of fatness usually with 1–5 or 1–9 levels (BCS points). Nine point BCS systems are more specific and preferred in domestic cats, dog, horses and other species and have been validated against direct and indirect

objective measures of fatness (German et al., 2006; Henneke et al, 1983; LaFlamme, 1997; Laflamme, 2005; Stevenson & Woods, 2006). One advantage of a 9 point body condition scoring system is that scores of 4 (moderate low) and 6 (moderate high) serve as warning zones where diet or management changes can be made to avoid ever reaching body conditions of increased health risk (low 1–3 and high 7–9 scores). Weights can provide the most specific measure of change in fatness, however body condition scoring is necessary in addition to weight to determine appropriate target ranges and also to track animals when weights alone are not indicative of BCS such as during growth and gestation. Body condition also does not require special equipment or animal training to achieve, although scorer training is needed.

A 9 pt. BCS scale has been developed for the lion based on 125 images collected from the internet and other institutions, 60 photosets collected from 2.4 lions at an AZA-accredited zoo, 26 of which were paired with weights, and 5 paired with palpations and transcutaneous ultrasounds collected over ribs, back, rump and tail while the animals were anesthetized (Fig 6, Fig 8). Although each species has unique conformation supporting the development of specific BCS systems, areas of fat accumulation are similar across many quadrapedal species, in particular: over the hips, the base of the tail, the torso and ribs, the backline, behind and over the shoulder, and the neck.

It is generally recommended that animals in zoos be maintained within the range of moderate body condition scores (4–6 on a 9 point scale). More extreme body conditions are associated with increased health risks, poor reproductive performance and reduced longevity in domestic cats and dogs (Laflamme, 2005). Palpation and transcutaneous ultrasound can provide a more accurate measure of fatness and should be used in conjunction with weights to calibrate visual assessment if possible.

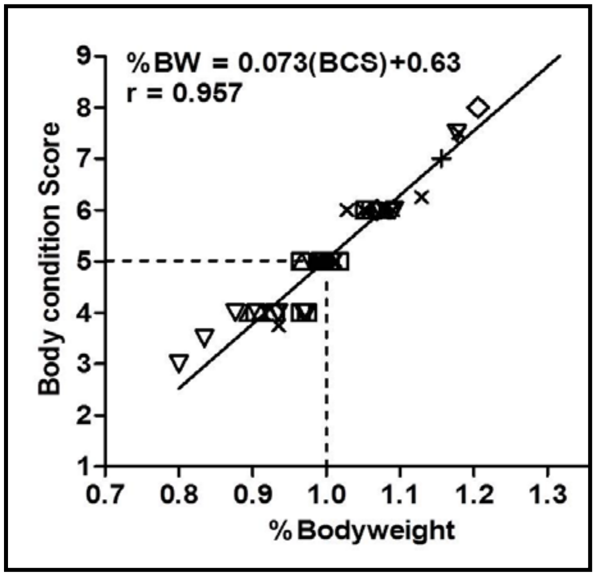


Figure 7. Plot of body condition score versus percent of moderate (BCS5) bodyweight for *Panthera leo* (1.0 open square, 0.1 x-symbol), *Panthera tigris* (1.0 open diamond, 0.1 plus sign), *Panthera tigris jacksonii* (1.0 open inverse triangle, 0.1 open triangle), *Panthera once* (1.0 open circle).

BCS scores showed a strong linear relationship (r=0.939) to weights for lions. This relationship was similar in other large felids so lion data were combined with data from 2.2 tigers (*Panthera tigris*) and 1.0 jaguar (*Panthera onca*) for a total of 50 weight/score pairs with pairs for each individual spanning at least 3 body conditions. Weights were normalized (weight at BCS 5 = 100%) and plotted against body condition scores (Figure 7). Linear regression for combined data clustered by animals gave a value of 7.3% change in bodyweight per unit BCS (95% confidence interval 6.3 to 8.3%, r = 0.957).

More specific body composition techniques exist and can further validate BCS scales in exotic animals, however these techniques are challenging or expensive to apply. Beyond the data reported above, body composition has not been assessed in lions, however it has been estimated from total body water from 14 wild lions in 2 studies (Clarke & Berry, 1992; Green et al., 1984). Average total body water was 64% and did not differ between males and females or immature vs. mature lions (P>0.05). This corresponds to an average fat mass of 13% bodyweight (range 3 to 21%). Studies in domestic cats using the same method, bioimpedance or DEXA, found fat masses of 23%, 28% and 5-55% bodyweight (Ballevre et al., 1994; Elliot, 2006; German et al., 2006). From these studies, an equation was derived to estimate body composition from body condition scores using a 9 pt scale in the cat (German et al., 2006):

%Fat Mass = 6.652(BCS)-14.07

Based on this equation an increase in 1 body condition score is equivalent to a 6.652% increase in bodyweight, very similar to the 7.3% estimated for large felids. The equation also predicts 0 fat mass at BCS 2 which would seem appropriate the BCS systems for lions presented above. Accordingly, the equation for estimating fat mass from BCS in domestic cats appears to be applicable to lions and other big cats, estimating 20% body fat corresponding to a BCS 5 out of 9. Extrapolating from this equation, wild lions ranged from 2.5 to 5.25 BCS, with an average BCS of 4 out of 9 (Clarke & Berry, 1992; Green et al., 1984).

Figure 8. Nine-point body condition scoring system for lions (*Panthera leo*)

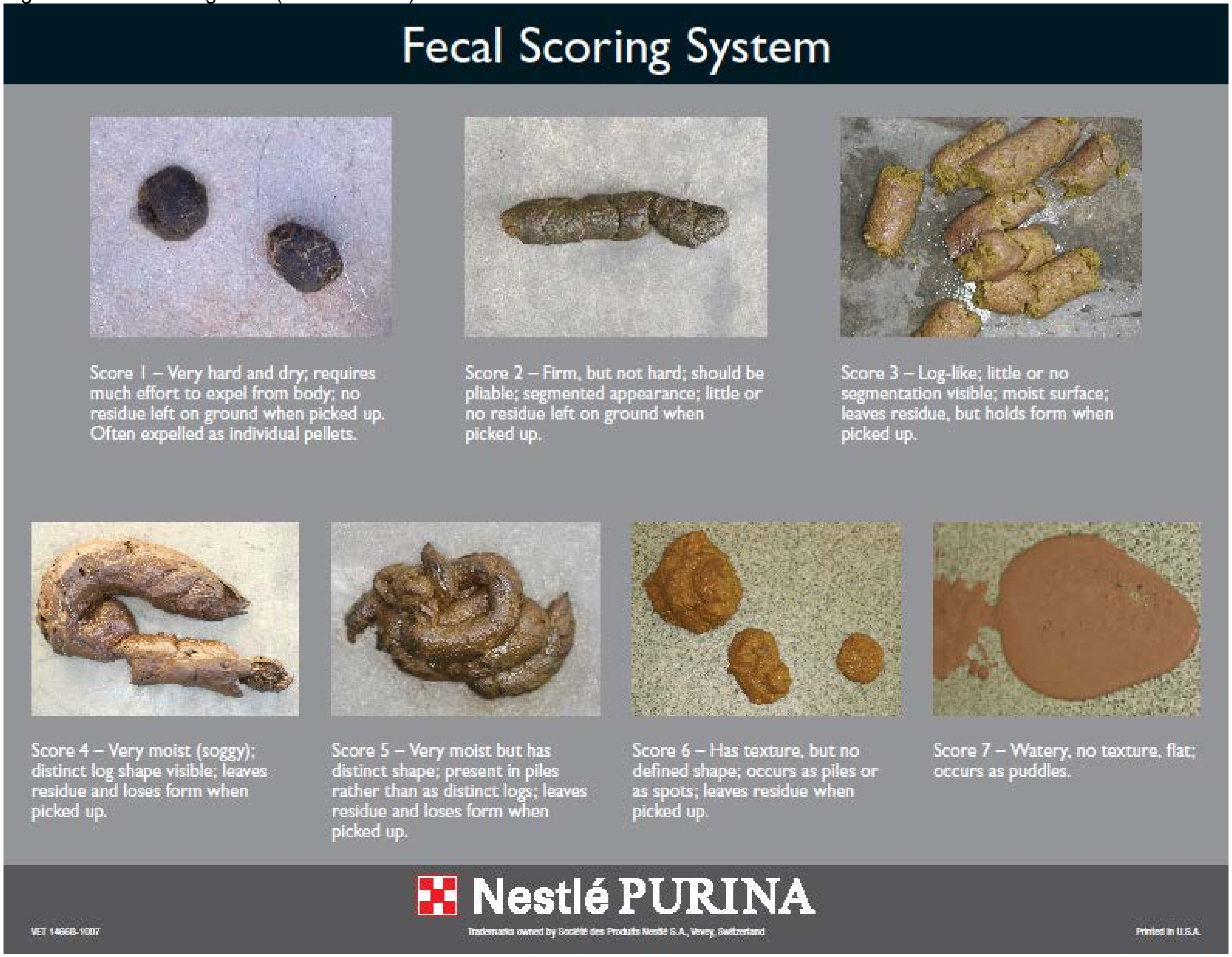
(1) Extreme Low (emaciated, no fat covering, skeleton visible)  	**Forequarters:** Neck thin & deeply shrunken. Shoulder wasted, vertical line of scapula visible. Angles of shoulder blade & arm sharp. Bones & joints clearly visible. **Midsection:** Multiple ribs visible with deep depressions between. Individual vertebrae visible. Waist shrunken & tucked. Sharp angles dividing shoulder, torso & hip. **Hindquarters:** Point of hip & ischium sharp & clearly visible. Bones of leg (femur & knee) clearly visible. Flank sunken. Sacral vertebrae visible. Tail base protruding above hip.
(2–3) Low (minimal fat covering, articulations angular & some bones visible)  	**Forequarters:** Neck thin & shrunken, sinews apparent but flowing into shoulder. Angles & bones of shoulder & arm prominent but with slight covering. Peak of scapula prominent. **Midsection:** Multiple ribs visible; abdominal muscles may be apparent. Vertebrae may be visible. Waist/belly shrunken & tucked. Abdominal skin flap may be apparent but not filled. Clear definition between shoulder, torso & hip. **Hindquarters:** Point of hip prominent but slightly covered. Ischium visible but blunt. Muscle & bones of upper leg angular but softened by slight covering. Sacrum flat or slightly depressed. Tail base becoming visible.
(4) Moderate/Low (slight fat covering, bones barely noticeable, articulations apparent but smooth)  	**Forequarters:** Neck cylindrical but discernible from shoulder. Muscles of shoulder apparent but slightly smooth. Peak of scapula apparent. **Midsection:** Some ribs visible; abdominal muscles apparent. Vertebrae rarely visible. Waist evident. Abdominal skin flap may be apparent with nominal filling. Smooth but noticeable delineation between shoulder, torso & hip. **Hindquarters:** Point of hip visible but covered. Ischium noticeable but rounded. Muscles of upper leg apparent & smoothed by slight fat covering. Sacrum sloped, but beginning to fill & round.

(5) Moderate (slight fat covering, bones not apparent, articulations visible but smooth)  	**Forequarters:** Neck filled in to flow smoothly into shoulder. Muscles of shoulder noticeable but with smooth covering. Peak of scapula noticeable but topline flows smoothly from neck into torso. **Midsection:** Ribs not visible; abdominal muscles noticeable as a transverse line. Vertebrae not visible; back smooth or heart-shaped & muscled. Waist noticeable as a smooth concavity. Abdominal skinflap may be present with nominal filling. Slight delineation between shoulder, torso & hip. **Hindquarters:** Point of hip barely noticeable, well-rounded. Ischium noticeable when walking, barely noticeable (flat/straight) when standing. Upper leg smooth & filled with slight muscle definition. Slope of hip becoming rounder.
(6) Moderate/High (noticeable fat covering, articulations becoming less noticeable)  	**Forequarters:** Neck filled & becoming continuous with shoulder. Muscles of shoulder apparent but covered with fat. Peak of scapula noticeable but topline flows smoothly from neck into torso. **Midsection:** Ribs not visible; abdominal muscles barely noticeable. Back smooth & rounded, becoming flat. Waist less discernable as a shallow depression. Abdominal skin flap filling with fat. Delineation between shoulder & torso but torso flows smoothly into hip. **Hindquarters:** Point of hip & ischium completely rounded. Upper leg smooth & rounded, muscle definition minimal/barely noticeable. Sacrum rounded.
(7–8) High (considerable fat covering, animal becoming rounded & bulging)  	**Forequarters:** Cheeks beginning to fill. Neck continuous between head & shoulder. Muscles of shoulder barely noticeable, covered in fat. Fat accumulating under neck & chest, & behind shoulder & arm. **Midsection:** Abdomen smooth, rounded & well-covered; ribs or muscles not visible. Back rounded & becoming flat. Waist almost filled, barely discernible. Abdominal skin flap apparent & thickened with fat. Shoulder barely differentiated from torso, but torso continuous with hip. **Hindquarters:** Point of hip & ischium covered & rounded. Hip & upper leg filled & convex throughout. Muscles of leg barely noticeable. Sacrum rounded, tail base flush & tail beginning to thicken.
(9) Extreme High (animal bulging & completely covered in a heavy fat layer)  	**Forequarters:** Cheeks filled out. Neck bulging & convex, continuous with head & shoulder. Shoulder rounded & muscles barely discernable. Pendulous fat accumulated beneath neck, chest, arms & abdomen. **Midsection:** Torso rounded & smooth, continuous with shoulder & hip. Back smooth & rounded or flat & table-like. Waist filled & not discernible. Thick, pendulous fat along undercarriage. **Hindquarters:** Hip & upper leg smooth & rounded. Muscles of leg not apparent. Tail noticeably thickened.

Fecal Scoring

A fecal scoring chart for lions has not been developed. In the literature, 1–5 scales are described without a photo record. To minimize this subjective assessment, a scale with photos is highly recommended. The attached chart should be used to provide consistency between evaluators.

Figure 9. Fecal scoring chart (Nestle Purina)



Den box
K. O'Connell

If space allows, an entire stall may be used by covering the front mesh with plywood or a tarp to provide privacy. Lions have also used larger boxes (2.1 m H x 2.1 m W x 1.5 m D [7 ft H x 7 ft W x 5 ft D]) and if the box is this tall a top is not needed. A box this size is also easier for staff to enter and clean.

Den boxes should be equipped with video cameras that can be monitored remotely from another part of the building. Cameras connected to a network can even be viewed from off site, which may be useful for managers to advise from home if there are concerns. While not as sophisticated as systems built specifically for animal facilities, those designed for home or small business surveillance will serve this purpose. A package of 4 night vision cameras with a DVR and monitor can be purchased for less than $500.

Birth facilities should have shavings, straw or grass hay added for bedding, although some females will remove all of it from the nest box and others will need to be monitored for ingestion. The bedding should be carefully inspected for dust, mold or possible inhalation risks to the cubs. The death of a cub did occur at one facility after aspiration of a tiny hay seed, although this was likely unavoidable and very rare.

As parturition draws near, animal care staff should ensure that the area is "baby-proofed." The birthing area and any holding area associated with it should be free of places where the cubs could get their head, feet, or other body parts caught. This could include large mesh, drains, pools, steps, gutters, drinkers, and tight spaces where furniture attaches to the wall or floor. Cubs should also be restricted from climbing up onto elevated areas until they are capable of navigating them safely. Bedding can also be used to provide a soft landing in areas where cubs could climb and fall.

7.5 Assisted Rearing

Although mothers may successfully give birth, there are times when they are not able to properly care for their offspring, both in the wild and in *ex-situ* populations. Fortunately, animal care staff in AZA-accredited institutions are able to assist with the rearing of these offspring if necessary.

The AZA Lion SSP does not recommend elective hand rearing of cubs. However, if a cub is in danger, ill, injured or being neglected, intervention is needed. If an institution does not wish to hand rear, humane euthanasia is an acceptable form of intervention so that the cub does not suffer unnecessarily. Assisted rearing by human caretakers is also an option after intervention, and institutions considering this option should make preparations well in advance of parturition. Keepers, managers, and veterinarians should discuss the criteria and procedures for intervening well in advance as well. By the time the cubs are born, everyone will be tired and under pressure, so advanced planning will help avoid emotional decision-making and disagreements later on when timing will become critical.

Hand-reared females of most species will rear their own young if they were peer-reared with a sibling, or another young felid, provided they are not otherwise overly imprinted on humans. This can be avoided by rearing with a conspecific or even another suitable animal. In the event of a single birth, every effort should be made not to hand-rear the young alone. The AZA Lion SSP Coordinator can provide information on possible similar age cubs at other institutions for peer rearing of singletons.

If conspecific young are not available, a domestic dog can be introduced. This relationship needs to be monitored closely because over a short period the lion will mature to the point where injury to the dog is a serious concern (A. Blue, personal communication). This companionship will provide valuable play experience necessary for proper socialization and normal developmental skills, factors that are critical in the lion's later success in dealing with conspecifics.

Foster rearing has been successful if a suitable dam is readily available (G. Noble, personal communication, 2006). Ideal candidates are other females in the pride with previous cub experience, and females that have recently lost cubs may even be able to nurse cubs.

Hand-rearing protocols: Ideally, criteria for hand-rearing a lion cub should be well established, and a management plan in place before the female gives birth. This will help to ensure that supplies, equipment, and support are available and on-hand should they be needed. It will also help guide the process during a time when quick decision-making may be necessary. Hand-rearing any animal requires around-the-clock care, and while an exhausting endeavor, it usually works best if only one or two caregivers provide the primary care during the first critical few weeks. Too many caregivers can cause problems with getting young cats to nurse and eliminate reliably, and subtle changes in the cat can often go unnoticed when too many people are involved. If it is necessary that multiple caregivers are involved, one person should set the feeding schedule and provide guidance on how to mix the formula (Hedberg, 2002).

When hand-rearing young felids, staff should pay close attention to three critical areas: volume of consumption per feeding, total daily consumption, and daily weight gain. Other important factors are stool quality, frequency of urination, and general condition (i.e., alertness and responsiveness). A daily chart should be maintained for recording these factors.

Medical Assessment
When neonates are initially removed from the dam, they should first receive a general physical. While conducting initial physical exams, problems such as cleft palate, wounds, herniated umbilical cord, and physical deformities should be reviewed. Because neonates do not have a fully developed immune system, the umbilical cord site may be a major source of infection; this site can be cleaned by applying antiseptic (solution of 50% betadine, 50% water) every 4–6 hours until the cord dries out and falls off. If vital signs are not within acceptable ranges, issues of dehydration, hypothermia, or hyperthermia may have to be addressed first. Dehydration can be determined by pulling up on the skin on the back of the neck. If the skin does not retract immediately, and stays suspended, warm fluids need to be administered by tube into the stomach, or subcutaneously, by a veterinarian. To regulate temperature, young may need to be maintained in a warm or cool environment, as required.

Milk Composition
In the domestic cat nutrient composition of milk is affected by stage of lactation with protein increasing from early to late lactation (Table 21 below). A wide range of fat levels have been reported for domestic cat milk (3–14%) which may be attributed to maternal diet, milk collection method, and/or methods of analysis (Oftedal & Iverson, 1995). The nutrient content of domestic cat milk is comparable to domestic dog milk (Oftedal & Iverson, 1995), therefore formulas appropriate to dogs should also be appropriate for cats. The selection process for a milk replacer should be based on the nutrients and their levels. Depending on the data used to formulate a product, it may or may not be appropriate for the target species, and/or may be applicable to more than one.

Data specific to lions is limited (Table 21), but shows similar trends in protein and slightly lower lactose than the milk of domestic cats. Most poignantly, fat values at the low end of the range reported for domestic cats and reflected in milk replacer formulas may be inappropriate for the lion (Table 21). Though commercial cat and dog replacers have resulted in healthy young lions, lower initial growth in hand reared animals compared to parent reared cohorts (Figure 4, Figure 5, Table 6) could be due in part to the difference in the composition of mother's milk and the milk replacers.

Table 21. Nutrient composition of domestic cat milk, lion milk, and commercial milk replacers

	Stage of lactation	Dry Matter, %	Fat, %	Protein, %	Lactose or Carbohydrate, %
Domestic cat[1]	0–43 days	[2]	3.4–5.3	4.0–7.5	3.4–4.3
Domestic cat[3]	6–8 days	[2]	10.9	11.0	3.4
Domestic cat[4]	0–6 weeks	25.3–28.6	13.1–13.6	6.7–10.0	3.9–4.1
Lion, 40 hours[5]	40 hours	19.2	11.4	6.0	2.65
Lion, 10 days[5]	10 days	16.7	13.7	8.5	[2]
Lion, 45-90 days[6]	45–90 days	26.8	8.7	11.8	3.2
Lion[7]	unknown	36.1	18.9	12.5	2.7
KMR[8]	Liquid	18.0	4.5	7.5	4.7
Milk Matrix 42/25[8]	Reconstituted	17.7	5.2	7.9	3.4
Esbilac[8]	Liquid	15.0	6.0	4.5	2.4
Milk Matrix 33/40[8]	Reconstituted	15.8	6.9	5.5	2.5

[1](Keen, et al., 1982)
[2]Values not reported
[3](Folin et al., 1919)
[4](Jacobsen et al., 2004)
[5](de Waal, et al., 2004)
[6](Oftedal & Iverson, 1995)
[7](Shaul, 1962)
[8]PetAg, Inc. Hampshire, IL. Reconstituted formulas are powders mixed with water following the label instructions (1 part powder to 2 parts water).

Formula Selection

From a recent survey, most institutions used Esbilac to hand rear lions (9 of 13 respondents) compared to KMR (3) and Milk Matrix 33/40 (1). Custom formulas have been suggested but follow up data on amounts fed, stool condition, and growth were not provided (Hedberg, 2002). Formulation based on mother's milk is likely to be closer to optimal. If formulas do not contain taurine, cubs should be supplemented with 250 mg per day to meet the increased requirement for taurine by cats (NRC, 1986). Formulas fed as specified by the manufacturer should not require additional vitamin and mineral supplementation. Many institutions use products to assist with the breakdown of lactose. Considering some commercial products may contain levels of lactose greater than lion milk, use of these products may be warranted.

If colostrum is not available to a lion cub within 16 hours of birth, adult cat serum can be given. Based on recommendations made for tigers, a minimum of 75mL serum/kg should be given as an intraperitoneal injections or a subcutaneous injection twice a day (Hedberg, 2002).

Amount to Feed

Amount of formula fed should be based on body weight. Average daily gain for parent reared lions was approximately 100 g/d during days 0–100 while hand reared lions grew more slowly at approximately 70 g/d. Early growth data is not available for young wild lions. A target energy intake to support this growth can be estimated based on the previous mentioned equation and knowing the energy content of the formula and solids offered. Caloric goals can be estimated as described above: ME_g kcal/d = ME_m + 1.9(ADG) = $(125BW_{kg}^{.75})$ + 1.9(100). Amounts should be based on achieving target gains and body condition.

Considering the estimated energy content of the commercial formulas, this amount may be up to 29% of body weight initially, dropping to 20% at 10 days and 11% at 70 days. In comparison to the data on lion milk, this growth may be achieved with 16% of body weight dropping to 6% of body weight at 70 days. Most hand rearing protocols do not significantly exceed 20%. Thus it is not surprising early growth goals are not met. Frequent adjustment to the amount fed based on body weight facilitates consistent growth. Cubs should be weighed daily, and should be weighed at the same time of day to allow accurate comparison of weight over time. Weighing before or after a feed can significantly affect the weight.

Feeding Schedule

The maximum stomach capacity of a carnivore may be, in general 5–7% of body weight. Consequently, to feed 20% of body weight, a minimum of 5 feeds should be offered. Some institutions start with 7–10 feeds for the first 10 days. Consistent, small meals can help avoid gastrointestinal tract stress. Animals should not be fed as much as they will take; this often leads to overfeeding and diarrhea.

Feeding Apparatus
In general, felids of the genus *Panthera* nurse well from human nursing bottles. Preemie nipples or cross cut normal nipples can also be used. A wide selection of nipple types and openings should be available, as some trial and error may be needed to find the best type to use with each individual cub. Bottles and bowls should be cleaned and sanitized between feedings. After cleaning, bottles can be boiled to avoid contamination from the environment.

Weaning
The weaning process may be instituted as soon as the incisors erupt, which can be around 5 weeks of age (Hedberg, 2002). Solids can be introduced in the form of a nutritionally complete canned cat food or a blended nutritionally complete raw meat diet. By this time, the cubs should be consuming formula from a bowl. The blended canned or raw meat diet can be added to the formula in the bowl. If canned cat food is used, it will need to be mixed with the raw meat diet and gradually decreased and removed over time. The benefit to using a canned diet initially is to delay microbial introduction to the cub's gastrointestinal tract. However, several species have been weaned onto raw diets without apparent ill effects. At this time, once the cub is consistently consuming solids, the amount of formula offered can be slowly decreased. Complete removal of formula can be attempted as early as 7.2 weeks, and as late as 12 weeks. Balanced calcium and phosphorus ratios should be maintained throughout the hand-rearing process. Commercial kitten and puppy milk replacers provide the appropriate ratio. However, during weaning the ratio can become skewed if the cubs are fed baby food, muscle or organ meat. In such instances, calcium supplementation may be required until the lion is weaned onto a nutritionally complete commercial diet.

Growth
Growth curves for parent, hand reared, and wild lions are shown in Figures 4 and 5. Though other authors have suggested 100 g average daily gains increasing to 200 g when solids are introduced (Hedberg, 2002), gains of 200 g were not observed before 70 days of age, when animals are nearly or completely weaned (Table 6).

Food Safety/Sanitation
Formula should be stored refrigerated separate from human consumption food. Formula over 24 hours should be discarded. Bottle and nipples should be cleaned and disinfected between feeds.

Record Keeping
Accurate records are critical to assess progress of the hand rearing process. Date, day, body weight, formula strength, amount consumed, stool condition, urination/defecation (stool quality), medications/treatments, comments on behavior including feeding response should be recorded. Electronic files facilitate quick assessment and summarizing.

Feeding and Eliminating
When feeding young felids, they should be placed on their stomach on a flat surface (e.g., table). Cubs held in an upright or head back position during feeding are more prone to aspiration and death. 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 cloth. Only slight pressure is needed to help guide the fecal material through the digestive tract and out the anal canal. After a week, this procedure can be reduced to two times a day. After the young begin eating solid food, this procedure can be reduced to one time per day. Most young will defecate on their own at 8–10 weeks, if not sooner.

Exercise and Socialization
After the cub starts walking, it is vital that sufficient space and time be provided to allow it to run and climb, and it should be provided with low climbing structures. Enrichment should be provided to promote stalking and pouncing. Although biting and clawing behaviors toward keepers should be discouraged, other natural behaviors should be encouraged. Providing the cub with a variety of safe toys will help keep them developmentally challenged, and may help to minimize the development of undesirable or stereotypic behaviors.

Shaping a cub's behavior through positive reinforcement and identifying the causes of undesirable behavior will help to prevent a cub from biting or displaying problematic behaviors later on. When caregivers provide opportunities for socialization, they help develop the cub's confidence and can reduce more dangerous behaviors. Leash training can begin at an early age, and can help facilitate outings, exercise, and control while the cubs are young and more easily handled if large contained areas are not available (Hedberg, 2002). It should be stressed that the leash is only a temporary method of restraining a young cub under 6 months of age. See Chapter 7 for more information on socialization of cubs with staff.

Hand reared cubs should be introduced to adult lions whenever possible at the earliest possible age. Several cubs have been reared using a hybrid rearing technique that allows the cubs to be housed with conspecifics and bottle fed by staff. Cubs should be housed in visual access to conspecifics as soon as they are stable and introductions can proceed as described in Chapter 4.

Recommended Equipment

- Isolette/incubator (set at 29 °C [85 °F])
- Sheepskins/synthetic fleece pads
- Heating pad (set on low with a double thickness of bedding place over half the pad enabling neonates to move if they become too warm)
- Bottles/nipples
- Milk replacer
- Supplemental lactase enzyme (Lactaid®)—decreases gastrointestinal upset
- Electrolytes such as Pedialyte can be used in place of water for first few feedings or if diarrhea develops - Scale to measure weights daily
- Body temperature can be monitored daily to determine when the neonates are able to maintain their body temperature

7.6 Contraception

Many animals cared for in AZA-accredited institutions breed so successfully that contraception techniques are implemented to ensure that the population 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 contraceptive methods most suitable for lions are outlined below but zoos are encouraged to contact the SSP before contracepting animals, particularly permanent sterilization. More details on products, application, and ordering information can be found on the AZA Wildlife Contraception Center (WCC) webpage: www.stlzoo.org/contraception and in Asa and Porton (2005).

The progestin-based melengestrol acetate (MGA) implant, previously the most widely used contraceptive in zoos, has been associated with uterine and mammary pathology in felids and suspected in other carnivorous 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 now recommends GnRH agonists, e.g., Suprelorin® (deslorelin) implants or Lupron Depot® (leuprolide acetate) as safer alternatives. Although it appears safe and effective, 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 those associated with gonadectomy, especially weight gain, which should be managed through diet. Suprelorin® was developed for domestic dogs and has been used successfully in lions and other felids (Berschinger et al., 2001; Munson et al., 2001).

<u>Gonadotropin releasing hormone (GnRH) agonists [Suprelorin® implants, or Lupron Depot®]</u>: GnRH agonists 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 (which will result in mane loss), 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. Then, down-regulation follows the initial stimulation in 3-4 weeks. The stimulatory phase can be prevented in females by daily Ovaban (megestrol acetate) administration for one week before and one week after implant placement (Wright et al., 2001).

11.1 Lion Bibliography by Subject

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11.2 Web Resources

Lions and Other Felids	
www.catsg.org	IUCN Cat Specialist Group
www.cbs.umn.edu/lionresearch/	Lion Research Center (Dr. Craig Packer's lab)
www.panthera.org	Panthera

Training and Enrichment	
www.enrichment.org	The Shape of Enrichment
www.animalenrichment.org www.animaltraining.org	Disney's Animal Kingdom sites (includes information on the SPIDER model)
www.clickertraining.com/	Karen Pryor Clickertraining
www.aussiedog.com.au/	Enrichment Vendor
www.desertplastics-abq.com/Animals.asp	Enrichment Vendor

AZA	
www.felidtag.org	AZA Felid TAG
www.aza.org	Association of Zoos and Aquariums
www.stlzoo.org/contraception	AZA Contraception Center

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