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Food Intake and Mass Gain of Hand-Reared Brown Bear Cubs

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Five orphaned European brown bear cubs (*Ursus arctos*) from 3 litters were hand-reared from the ages of 1–4 months. Body mass initially ranged from 1.7 to 2.8 kg. Growth rates were monitored with reference to diet. Over a period of 3 years, 6 different feed formulas were used. The first 4 formulas were given with bottles until an average age of 133 days. Conversion to mass in the first 10 months ranged from 3.5 to 32.0 g of food per gram of body mass (or 38.1–192.6 kJ of gross energy/gram body mass), and was affected by type of diet. High fat content increased, whereas high carbohydrate content decreased the conversion rates. Formula 3, with 12.0% protein, 23.9% fat, and only 0.2% carbohydrates, simulated values found in bears' milk and produced the best growth rates. Formula 6 (bread, fruits, and meat) was used from ages 7 to 35 months, and over this period, the efficiency of gross energy conversion decreased gradually, by an eventual factor of 3.8. Hand-reared cubs ranged from 1.3 to 2.7 times heavier than 17 wild cubs measured at matching ages. Wild mass is probably limited by maternal hibernation, and by the largely herbivorous nature of the diet.

Key words: ***Ursus arctos*, food conversion, growth**

INTRODUCTION

Bears are born very small (< 1% of mother's mass), in the middle of winter, when no food is available. Dams produce very concentrated milk [Jenness et al., 1972], and on this diet, cubs achieve enough growth within 3–4 months to be able to leave the den and follow the mother in spring foraging. Suckling decreases in importance with age, but continues until at least 1.5 years of age.

The food intake and early growth of European brown bear cubs (*Ursus arctos*) have not been studied. In this respect, much more is known about American black bears, *U. americanus*. Hock [1966] compared caloric intake and mass gain in two black bears from the age of 21 days. Rausch [1961], Butterworth [1969], and Hulley

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TABLE 1. Basic data on life history of 5 tested European brown bear cubs

Litter	Cub number	Estimated birth day	Start of hand-rearing	End of test
A	1	08 Jan 88	10 Feb 88	30 Oct 91
A	2	08 Jan 88	10 Feb 88	30 Oct 91
B	3	15 Jan 88	24 Feb 88	28 Nov 90
B	4	15 Jan 88	24 Feb 88	16 Jul 88
C	5	— Jan 88	11 Apr 88	18 Jul 88

[1976] have described other aspects of postnatal growth in this species. Oftedal and Gittleman [1989] have compared patterns of energy output during reproduction in a large number of terrestrial carnivores, including 3 species of bears.

We monitored the growth rate, with special reference to the diet, in 5 orphaned European brown bear cubs from 1 and 4 months up to 4 years of age. The influence of different diets in terms of their similarity to bear milk was analyzed, and the body mass of hand-reared and wild cubs of equivalent ages was compared.

MATERIALS AND METHODS

The 5 female cubs of this study came from 3 litters (Table 1) born in Gorski Kotar, Croatia. The cubs were presented for hand-rearing after they were either found out of the den with no mother around (litter A), after the mother was accidentally chased out of the den and did not return within 48 hrs (litter B), or after wandering unaccompanied into a village (litter C). Litter A had a third cub, which died within 24 hr of coming into our hands. Postmortem examination revealed pulmonary edema and emphysema, with a large milk curd obstructing the stomach. Data from 17 other cubs nursed by their mothers [from Frković, 1983, and collected by us] were used for comparison with the hand-reared litters. Birth dates of the orphans were estimated by extrapolation from observed daily mass gains back to mass at birth [Hock, 1966]. The condition of features, such as healing of the umbilicus, hair growth, and degree of eye opening, was also used. In all later calculations, we used January 12 as the mean date of birth for all 5 cubs.

Six different feed formulas were used over the course of the study. The first 4 formulas were individually bottle-fed, and all quantities consumed were recorded. After the cubs began feeding as a group on solid food, the total consumed was apportioned equally to each bear. Food intake was recorded as the mass of the prepared meal with moisture included. The nutritional value (gross energy) of each formula was obtained by computer analysis. The first 2 mixtures were based on artificial formulas for human infants. Formula 3 was prepared by the second author to simulate bear milk.

Although a variety of body measurements were collected during the study period, only data on body mass and length are presented in this report. After the age of 3 months, cubs had to be chemically immobilized (11 mg/kg Ketamine, 6 mg/kg Xylazine) in order to obtain measurements.

TABLE 2. Compositions of feed formulas served to European brown bear cubs compared to the brown bear milk (%)

Feed formula ingredients (% volume)	Total solids	Prot.	Fat	Carbo-hydrates	Ash	Ca	P	kJ/g
1. Human infant food	21.1	2.8	4.5	13.0	0.8	0.10	0.04	4.35
(Energy distribution %)		11.0	39.0	50.0				
Infant food 1[a] (9.5)								
Infant food 2[b] (58.1)								
Infant food 3[c] (29.5)								
Sugar (2.9)								
2. Human infant food + cream + yolk	31.4	6.0	14.0	10.0	1.2	0.13	0.15	7.95
(Energy distribution %)		12.6	66.3	21.1				
Infant food 2[b] (44.0)								
Infant food 3[c] (10.6)								
Yolk (17.6)								
Cream (30% fat) (27.8)								
3. Bear milk simulation	38.0	12.0	23.9	0.2	1.2	0.27	0.11	11.05
(Energy distribution %)		18.2	81.5	0.3				
4. Bear milk simulation + cow milk	26.4	8.1	14.7	2.2	1.1	0.22	0.10	7.28
(Energy distribution %)		18.7	76.2	5.1				
Bear milk sim. (55.4)								
Cow milk (44.6)								
5. Cow milk + mush + paste	24.6	5.3	5.7	12.2	1.2	0.09	0.12	5.06
(Energy distribution %)		17.5	42.3	40.2				
Cow milk (66.7)								
Corn mush (17.0)								
Wheat paste (16.3)								
6. Zoo adult bear feed	33.3	3.7	3.6	24.2	0.9	0.03	0.09	6.02
(Energy distribution %)		10.3	22.5	67.2				
Wheat bread (31.1)								
Apples (64.1)								
Beef meat + fat (4.8)								
U. arctos horribilis milk[d]	40.6	11.1	22.3	0.6	1.5	0.35	0.23	10.38
(Energy distribution %)		17.9	81.1	1.0				

[a]Humana O[R] (for low weight infants).
[b]Humana 1[R] + Humana 2[R] (standard infant food).
[c]Humana 9[R] (antidiarrhea infant formula).
[d]from Jenness et al. [1972].

RESULTS

Results are presented according to the feeding sequence of the different formulas. Formula composition is presented in Table 2, and periods of use, consumed amounts, and conversion rates for each are presented in Table 3.

Formula 1 was patterned after human baby formulas and, although the cubs accepted it, they had constant diarrhea. The mean daily consumption of 508 g (116 g of dry food mass) was fed in 6 meals per day on the average (range, 5–8).

The second formula added egg yolk and cream with 30% fat to the human baby formula mixture and was offered at ages 44–81 days. Daily consumption for this period was distributed over 5.2 meals (range, 4–8). At 73 days of age, cubs could drink water, and at 75 days, they first began to take food from a dish.

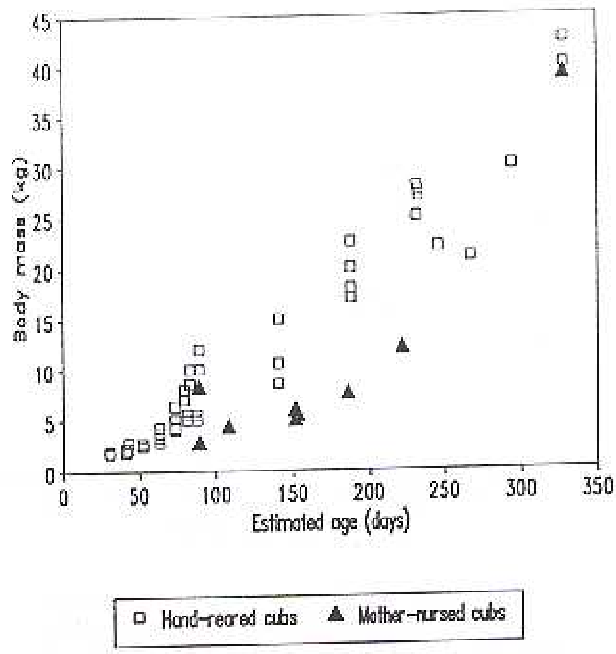

Fig. 1. Relationship between age and body mass for hand-reared and mother-nursed European brown bear cubs.

for body mass (Fig. 2). The ratio of body mass to body length was greater in the hand-reared sample.

DISCUSSION

The first formula used in this project was composed with no attempt to simulate the content of bear milk. It had a high carbohydrate content and was relatively low in fat and protein. In this formula, 50% of the energy was in carbohydrates and 39% was in fats.

With the second formula, an attempt was made to increase the similarity to bear milk by adding fat (cream) and protein (egg yolk). Fat became the major energy source (66%), whereas carbohydrate energy dropped to 21%. Consumption with this diet increased by 22%, and a 2.2 times increase in mass gain was seen. Butterworth [1969] fed an American black bear cub for the first 8 weeks of life with a formula consisting of equal parts of evaporated milk, water, and light cream, fortified with egg yolk. Hulley [1976] fed American black bear cubs with evaporated milk diluted with water in a ratio of 1:3 for the first 2 days, 1:2 for the next 5 days, and 1:1 until the transfer to solid food. It is interesting to note that cubs in his study began to drink from a dish at about the same time (72 days of age) as reported here. An American black bear cub is described by Hock [1966] as showing a mass gain of 137 g/day at the age of 80 days, with 2,001 kJ ingested. This represents a gain 3.7 times higher per kJ ingested than he found for the same cub at 20 days of age, but is 3.2 times less than we observed in our cubs at the comparable age of 80 days.

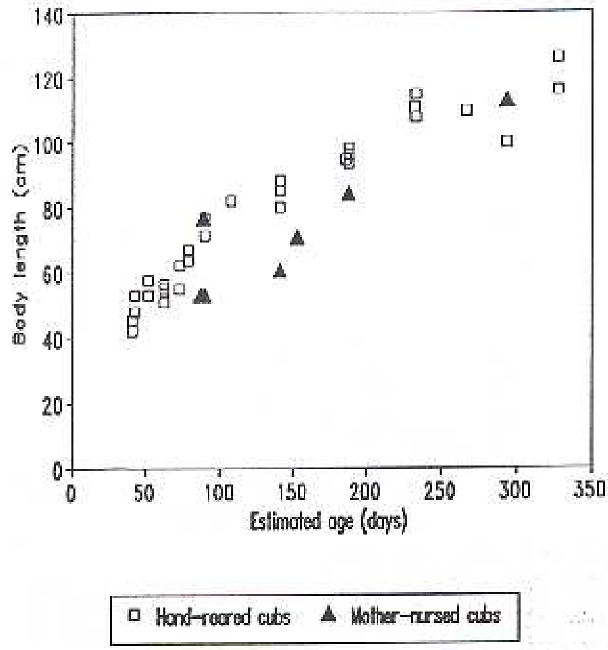

Fig. 2. Relationship between age and body length for hand-reared and mother-nursed European brown bear cubs.

The third formula was a simulation of brown bear milk as described by Jenness et al. [1972]. Over 40% of the milk solids of bears has a high caloric content, comparable only with the milk of cetaceans, pinnipeds, and certain rodents, but not with other fissipeds. In our mixture, the fat content from vegetable oil was the major source of energy (82%), with no carbohydrate energy at all. Despite a slight decrease in daily consumption, mass gain and conversion were highest with this formula. Compared with the mean values for all formulas used (including this one), the gain was 1.8 times higher, the conversion rate per mass of food was 5.0 times higher, and the caloric value was 2.8 times greater than the average.

The mixture of simulated bear milk with full cow's milk showed a daily mass gain that was 1.8 times smaller than from simulated bear milk. Also, the conversion rate was 2.2 times lower in relation to the amount of food consumed, and 1.4 times lower in relation to caloric value. Cub 5 came into our hands in very poor condition at the age of 3 months, with only 1/3 of the average mass of the other 4 cubs at that time (2,730 vs. 8,500 g). However, with a below average consumption rate, she showed the highest daily gains and conversion rate, i.e., 5.3 g food (38.6 kJ) per gram of mass gain.

The fifth formula was the first solid food, and was rich in starch (40% energy). Bottle feeding was abandoned as a feeding practice from the age of 135 days. By comparison, Hulley [1976] transferred an American black bear cub to solid food at 107 days. On formula 5, the daily gain and the conversion rate of caloric value did not change, but the conversion per mass of food was 1.6 times lower than when still bottle feeding. By the end of the period of feeding formula 5 (186 days of age), the largest cub was only 27% larger than the smallest, and mean mass was 18,800 g.

During the ~1.5 months of free living and feeding on natural foods, cub 3 gained only 20% less mass than would have been expected from our hand-rearing results. The composition, volume, and caloric content of foods consumed during this period are unknown. However, the mass at return suggests that social rather than nutritional factors were responsible for the return to captivity.

The sixth formula (the standard adult bear diet at the Zagreb Zoo) was the richest in carbohydrates and the poorest in fat of all diets fed, with 67% of energy derived from starch and 23% from fat. Over the period of 1,165 days in which it was used, the rates of conversion reached their lowest value. In the first period, i.e., up to the age of 10 months, the highest average daily mass gains were recorded, but the conversion rate of food mass was nevertheless 2.7 times lower, and the caloric value 3.1 times lower, than those during the feeding of formula 5. During the second year of life, the mass gain rate decreased by 1.6 times compared to the first 84 days of feeding on formula 6. In the cubs' third and fourth years, the gain was another 2.2 times lower, due to the completion of the subadult phase of growth.

These data indicate four distinct growth periods, based on the number of days required for body mass to double. Up to about the age of 4 months, the body mass doubled every 32 days. From 5 to 10 months, doubling occurred every 135 days. In the second year of life, the rate was every 375 days, and in the third and fourth year, every 1,755 days. The influence of different feeding formulas was apparently of less importance to the rate of doubling in mass than the phase of growth itself.

Rausch [1961] and Hock [1966] reported that artificially fed American black bear cubs attained a greater mass than mother-nursed cubs of matching ages. From the measurements reported by these two authors and by Butterworth [1969] for another American black bear (total of 15 captive, 9 wild cubs > 1 year of age), we calculated linear regression growth curves for both groups. This calculation revealed that at the start of artificial feeding at ages 0.5–3 months, hand-reared cubs were on the average smaller than mother-nursed ones. We assume this is because malnutrition at the time cubs are rescued and taken for hand-rearing is fairly common. However, around the age of 105 days, body mass in wild and captive-reared cubs was equal, and later on, the mass of hand-reared cubs was progressively greater until a doubling of that of wild cubs occurred at ~310 days. Corroboration of this trend is found in our data on European brown bear cubs (Fig. 1). Differences between captive and wild-reared cubs in body length, while favoring hand-reared, were smaller, however (Fig. 2). This indicates that unrestricted feeding results in greater body mass from a combination of faster general growth (body length) and larger fat deposits.

Oftedal and Gittleman [1989] demonstrated that bears, in comparison to other terrestrial carnivores, are extreme in the smallness of cubs relative to dam's mass, as well as in litter metabolic rate, postnatal growth rate vs. dam's size, and milk energy output at peak lactation. They discuss three contributing factors: hibernation, herbivorism, and maternalism. Though limitations imposed by hibernation contribute to small litter mass and low milk output, these are to some degree compensated by high milk energy content from maternal body fat. Herbivorous/omnivorous feeding on foods of low digestible energy content may limit mothers' ability to acquire and process sufficient energy to support high milk volume and rapid litter growth. Single parenting, as seen in bears, vs. biparental or communal care systems in carnivores may increase the amount of energy required to acquire food or provide protection for the young.

According to data presented by Oftedal and Gittleman [1989], an American black bear cub nursed by its mother consumes 168 g of milk per day, or 5.8% of body mass, at the peak of lactation (~75 days of age). Our hand-reared cubs at the same age consumed an average of 707 g/day of formula, or 11.1% of their mean body mass. As stated earlier, they were more than twice as large as equivalent aged wild cubs at most stages of growth. A similar difference was documented by Rausch [1961] for American black bear cubs. We speculate that bears retain a phylogenetic potential for utilization of greater amounts of higher quality food than they would normally find in nature. The strikingly faster growth rate seen with artificial feeding may be part of a general capacity exhibited by bears worldwide as a response to varying environmental conditions. This potential may also be taken as further evidence of an incomplete evolutionary transition from a carnivore to a herbivore diet.

CONCLUSIONS

1. An artificial diet with 24% fat, 12% protein, and almost no carbohydrates simulates bears' milk, and was used successfully in bottle-feeding, orphaned European brown bear cubs. A high fat content increases the conversion rate, whereas high carbohydrate content decreases it.

2. Up to the age of 4 months, bottle-fed cubs doubled their mass every 32 days. From 5 to 10 months of age, doubling required 135 days, and in the second year of life, 375 days. Doubling required 1,755 days in the third and fourth years. The doubling of body mass was more strongly influenced by growth phases than by diet.

3. Five hand-reared cubs were from 1.3 to 2.7 times larger than 17 wild cubs at equivalent ages. In unrestricted feeding, they were capable of consuming roughly double the quantity of food that a nursing cub could obtain from its mother.

4. European brown bears appear to be able to ingest larger amounts of high quality food than they would normally find in the wild state, and consequently achieve greater body mass in captivity. Hibernation and the high degree of diet herbivory impose limits on growth rates and ultimate body size achieved by wild-living bear cubs.

5. In terms of feeding capacity, bears appear to exhibit substantial environmental adaptability, and are therefore able to opportunistically utilize abundant food resources.

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REFERENCES

Butterworth, B. B. Postnatal growth and development of Ursus americanus. JOURNAL OF MAMMALOGY 50:615–616, 1969.

Frković, A. Tragom markiranih medvjedića iz Lividrage u Gorskom kotaru. PRIRODA 71:72–73, 1983.

Hock, R. J. Growth rate of newborn black bear cubs (*Ursus americanus*). GROWTH 30:339–347, 1966.

Hulley, J. T. Hand-rearing American black bear cubs *Ursus americanus* at Toronto Zoo. INTERNATIONAL ZOO YEARBOOK 16:202–205, 1976.

Jenness, R.; Erickson, A. W.; Craighead, J. J. Some comparative aspects of milk from four species of bears. JOURNAL OF MAMMALOGY 53:34–47, 1972.

Oftedal, O. T.; Gittleman, J. L. Patterns of energy output during reproduction in carnivores. Pp. 355–378, in CARNIVORE BEHAVIOR, ECOLOGY, AND EVOLUTION. J. L. Gittleman, ed. Chapman and Hall, London, 1989.

Rausch, R. L. Notes on the black bear, *Ursus americanus* Pallas, in Alaska, with particular reference to dentition and growth. ZEITSCHRIFT FÜR SAUGETIRKUNDE 26:77–107, 1961.