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Body condition scores of large carnivores in 44 European zoos

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Abstract
Zoo animals are often suspected to be prone to obesity, due to a combination of readily provided food resources and reduced opportunity for physical exercise. Here, body condition and selected husbandry conditions (the amount of food offered, enclosure size and number of enrichment measures provided) of ten large carnivore species (15–104 individuals per species) in 44 European zoos in seven different countries were assessed. A standardised body condition scoring (BCS) protocol (ranging from 1–9) was applied by a single investigator. In general, the BCS showed a close to normal distribution around the 'ideal' score of 5, with a slight right shift towards higher BCS; only in jaguar *Panthera onca* and lynx *Lynx lynx,* BCS suggested over-conditioned study populations. BCS tended towards positive correlation with body mass, except in tigers *Panthera tigris,* leopards *Panthera pardus* and the two bear species *Ursus arctos* and *U. maritimus.* Within species, the BCS was not systematically correlated with the amount of food, enclosure size or number of enrichment measures. The results suggest that while both under- and over-conditioned individuals exist, the study populations are largely in a body condition considered ideal. The lack of overarching correlations with simplistic husbandry proxies suggests that management of body condition occurs at the level of the individual institution with tailored measures.

Introduction

Obesity is a well-known problem in zoo animals (Bray and Edwards 1999) which can be closely associated with other health issues such as reduced reproduction or reduced lifespan (Adji et al. 2022; Das 2018). Carnivores have been named among the animal groups particularly affected by obesity (Dierenfeld et al. 1994). Species may differ in terms of their intrinsic susceptibility to obesity, for example due to a life history that includes seasonal resource fluctuations and the acquisition of body fat stores prior to hibernation. In this context, Mellor et al. (2020) found that lemur species adapted to natural feeds with a greater unpredictability of availability had a higher propensity for obesity in zoos. Among the carnivores, bears are renowned for their capacity to accrue body fat and might therefore be particularly prone to obesity in zoo settings (Lisi et al. 2013).

Obesity can in general be traced back to two main management issues—on the one hand, an amount of energy that is too high (Gerstner et al. 2016; Lisi et al. 2013) and on the other hand, reduced incentive to spend energy via mainly physical (but potentially also, to a much lesser degree, cognitive) activity. A connection that is often made is that small enclosure size limits activity (Brereton 2020) and hence might contribute to a lack of energy expenditure and subsequent obesity (Lutz and Woods 2012). Additionally, there may be little incentive or motivation for activity, regardless of enclosure size. One possible reason for this can be a lack of so-called 'enrichment'—structural or temporal factors of animal management that provide stimuli, such as objects, materials, scents or smells that motivate and elicit a diverse repertoire of physical behaviours, stimulating and fulfilling cognitive, social and emotional needs of the animals, and inciting them to spend energy (Ahloy-Dallaire et al. 2018; Meehan and Mench 2007; Mellen and Sevenich MacPhee 2001; Szokalski et al. 2012).

In order to monitor an animal's physical condition with respect to obesity, apart from regular weighing, various body condition scoring (BCS) methods are available (Schiffmann et al. 2017). The use of BCS has proved helpful in gaining an overview of the current body condition status of zoo populations as well as tracking progress towards targets in management programmes aimed at individual animals (Bray and Edwards 2001; Clark et al. 2016; Edwards et al. 2015; Schiffmann et al. 2019a). Typically, BCS can show correlations with body mass or a body mass index (Clavadetscher et al. 2021; Heidegger et al. 2016; Reppert et al. 2011; Schiffmann et al. 2019b), with body composition in terms of adipose tissue and muscle proportions (Morfeld et al. 2016), with the amount of food provided (Harper et al. 2001) and with the amount of physical activity (Smit et al. 2022; Warren et al. 2011) and can indicate a deterioration in body condition due to health problems (Hickman and Swan 2010).

The present study was part of a larger survey on feeding practices for large carnivores in European zoos (Kleinlugtenbelt et al. 2023a, b). The aim of the present study was to evaluate the population BCS status in samples of several large carnivore species kept in European zoos and to assess whether there were associations with body mass, enclosure size and the amount of food and enrichment provided.

Methods

This study was conducted with the support of the EAZA Felid TAG and Canid and Hyaenid TAG. The first author collected and compiled data from 44 zoos in seven countries by personal visits. One zoo sent their information in since a personal visit was not possible due to COVID-19 restrictions. The following species were observed: tigers *Panthera tigris* (26 zoos), lions *Panthera leo* (31 zoos), jaguars *Panthera onca* (7 zoos), leopards *Panthera pardus* (15 zoos), snow leopards *Panthera uncia* (13 zoos), cheetahs *Acinonynx jubatus* (15 zoos), lynxes *Lynx lynx* (16 zoos), hyenas *Crocuta crocuta* and *Hyaena hyaena* (11 zoos), brown bears *Ursus arctos*, including one brown bear-polar bear hybrid (15 zoos) and polar bears *Ursus maritimus* (12 zoos) to evaluate their body condition and record the enclosure size, and the amount of food and enrichment provided. This was done by following the responsible staff members on their daily routines with the selected species, both from behind the scenes and from the point of view of a visitor. Other results of these visits have been reported elsewhere (Kleinlugtenbelt et al. 2023a, b).

A nine-point body condition scoring protocol was used, following the ZIMS software (Species360, Minneapolis, MN, USA): 1: emaciated, 2: very under-conditioned, 3: moderately under-conditioned, 4: slightly under-conditioned, 5: ideal, 6: slightly over-conditioned, 7: moderately over-conditioned, 8: very over-conditioned, 9: obese. The Body Condition Scoring Resource Center of the AZA Nutrition Advisory Group was used as a starting point to find illustrated BCS schemes to guide the scoring. The BCS for lions from Daigle et al. (2015) was used for felids (Figure A1) except for the cheetah, for which the dedicated BCS of Reppert et al. (2011) was used. For bears, the five-point scale of the AZA Bear TAG (2009) with intermediate stages was used. For canids and hyaenids, the BCS of Laflamme (1997) was used. No specific training for applying BCS scores was instigated. All animals were scored on-site by the first author. Individuals of 1 year and older were scored. Due to the logistical difficulty of acquiring good photos for the many individuals per facility within the given time frame, BCS was only applied on-site and was not supported nor repeated using photographs.

Body mass data were collected as either the measured weight in kilogrammes or the estimated weight stated by the responsible keeper if a scale was not available in the visited facility. Notably, body mass was not estimated by the visiting author in order to avoid bias due to the impression of the body condition score. The enclosure size is the total extent in m² (as specified by the zoo) that the individual/group is able/allowed to use, including indoor boxes, but excluding separation boxes and enclosures which are not in use. If some enclosures were not strictly for one individual but rather were rotated on a regular basis, the average of the enclosures was used for the evaluations.

The amount of food was measured as the weekly amount per individuals in kg as fed, representing various items from meat, meat on the bone, to whole carcasses. If the amount was given for a whole group, then it was divided by the number of animals living in that group, excluding new born cubs and puppies, to give a value for the individual. Whenever possible, the first author weighed the amount of food provided during the visits. Food was expressed as a weekly amount to take fasting days and different feeding schedules into consideration.

An enrichment score, which is the number of different enrichment options used, was applied, following Table 1 in Hoy et al. (2010). In theory it has no upper limit. The enrichment options were grouped into categories but counted individually (Table A1). Olfactory enrichment was defined as addition of natural or artificial odours and scents, or intra- and inter-species rotation of enclosures. Auditory and visual enrichment are grouped together and are seen as the addition of sounds or visual stimuli. Tactile enrichment is the provision of novel objects: artificial, natural or parts of animals. Anything that is considered an alteration of physical space of the enclosure itself was considered to be structural enrichment (Hoy et al. 2010). Feeding enrichment includes anything food-related and edible, counted together (such as peanut butter, fruits, vegetables) and all feeding methods other than simply placing the food on the ground and hand feeding. The feeding methods were counted individually. Mixed-species enclosures are seen as social enrichment. All listed enrichment factors were counted and added to a sum without weighting of different enrichment options.

Not all information was available for all individuals. Statistical correlations between the BCS (a non-continuous measure, requiring non-parametric approaches) and both body mass and different husbandry variables was assessed with Spearman's rho. Additionally, a general linear model (using ranked data) was constructed with BCS as the dependent variable and the enclosure size, amount fed and enrichment score as the independent variables. All analyses were performed separately for each species (group), using R (R Core Team 2020). The significance level was set at 0.05, and values between 0.05 and 0.10 are referred to as trends.

Results

For most carnivore species in this study, the surveyed individuals show a close to normal distribution of BCS around the 'ideal' score of 5 (Table 1). Generally, the distribution tends to be slightly shifted to the right, i.e. towards obesity, in most species (Figure 1). The main exceptions are jaguars and lynx, with populations tending towards higher BCS overall, and the leopard with an unusual frequency of below- and above-mid value BCS.

Positive correlations between the (estimated or actually weighed) body mass and the BCS were evident in all species except tigers, lions and the two bear species (Figure 2, Table 2).

The enclosure size varied among zoos and was highest for bears and lowest for jaguars (Table 1). Enclosure size was generally not correlated with BCS, except—against the expectation in a positive way—in jaguar and leopard, and in the expected, negative way in snow leopards (Table 2).

The amount fed varied between 8 and 25 kg per week and generally reflected the body size of the respective species (Table 1). Again, in most species there was no correlation with BCS,

Table 1. Descriptive statistics of the large carnivores scored for their body condition (BCS ranging from 1-9) and the enclosure size, the amount of fresh food fed per week, and the enrichment score of the enclosure.

Species (n)	BCS median [min-max] (mean ±SD)	Enclosure size mean ±SD [min-max] m²	Amount fed kg as fed/week	Enrichment score n
Tiger (66)	5 [3-9] (5.2 ±1.1)	1840 ±2464 [15-10000]	25 ±11 [10-50]	13 ±5 [4-21]
Lion (104)	5 [3-9] (5.4 ±1.1)	5321 ±8826 [150-40000]	20 ±7 [10-35]	9 ±3 [3-17]
Jaguar (15)	6 [3-8] (5.9 ±1.5)	510 ±258 [135-900]	16 ±7 [7-30]	8 ±3 [5-11]
Leopard (26)	5 [2-7] (5.0 ±1.3)	671 ±1004 [40-3400]	11 ±3 [6-17]	10 ±4 [3-18]
Snow leopard (26)	5 [4-8] (5.7 ±0.9)	1082 ±1459 [40-5400]	13 ±4 [8-26]	10 ±5 [3-18]
Cheetah (47)	5 [3-7] (5.2 ±0.9)	2316 ±1981 [200-6700]	9 ±4 [5-21]	6 ±4 [0-17]
Lynx (20)	6 [4-8] (5.8 ±1.2)	1792 ±1341 [80-550]	8 ±3 [4-13]	7 ±4 [1-14]
Hyena (24)	5 [3-8] (5.1 ±0.9)	1209 ±965 [250-2850]	9 ±3 [4-12]	8 ±4 [1-17]
Brown bear (47)	5 [4-7] (5.0 ±0.6)	10709 ±8131 [413-25000]	30 ±15 [20-60]	5 ±8 [1-11]
Polar bear (32)	5 [4-7] (5.1 ±0.8)	5383 ±10263 [540-33400]	30 ±15 [20-60]	5 ±8 [1-11]

Table 2. Nonparametric correlations (using Spearman's correlation coefficient rho and the p-value) of the body condition score (BCS) with individual characteristics of the animals (right side of table) and results of a General Linear Model (GLM; based on ranked data; using the t-statistic and the p-value) assessing the relationship of BCS with enclosure size, the amount of food, and the enrichment score. Significant results are shown using[a], and trends as[b].

Species	Correlations with BCS				GLM		
	Body mass	Enclosure size	Amount fed rho P	Enrichment score	Enclosure size	Amount fed t P	Enrichment score
Tiger	-0.02 0.872	0.03 0.809	-0.22 0.075[b]	0.27 0.029[a]	0.64 0.525	-2.50 0.015[a]	2.46 0.017[a]
Lion	0.21 0.092[b]	-0.15 0.140	0.20 0.042[a]	0.04 0.673	-0.73 0.465	2.40 0.018[a]	-0.31 0.755
Jaguar	0.89 0.001[a]	0.58 0.025[a]	0.49 0.092	-0.07 0.818	2.71 0.024[a]	0.84 0.423	-0.75 0.473
Leopard	0.27 0.229	0.41 0.040[a]	-0.07 0.730[b]	0.08 0.702	3.11 0.005[a]	0.68 0.502	2.13 0.044[a]
Snow leopard	0.49 0.048[a]	-0.47 0.016[a]	0.39 0.047[a]	0.29 0.155	-1.38 0.182	1.24 0.229	0.78 0.442
Cheetah	0.45 0.003[a]	0.06 0.695	-0.11 0.469	0.32 0.027[a]	050 0.623	0.50 0.618	2.70 0.010[a]
Lynx	0.95 0.051[b]	-0.24 0.301	0.26 0.307	0.03 0.908	-0.72 0.485	1.89 0.079[b]	1.43 0.176
Hyena	0.60 0.088[b]	0.24 0.280	0.20 0.338	0.10 0.657	0.79 0.440	0.46 0.648	0.45 0.659
Brown bear	-0.01 0.953	0.09 0.646	-	0.08 0.588	0.56 0.578	-	0.70 0.486
Polar bear	-0.55 0.016[a]	-0.31 0.091[b]	-	0.07 0.703	-1.35 0.189	-	-0.34 0.735

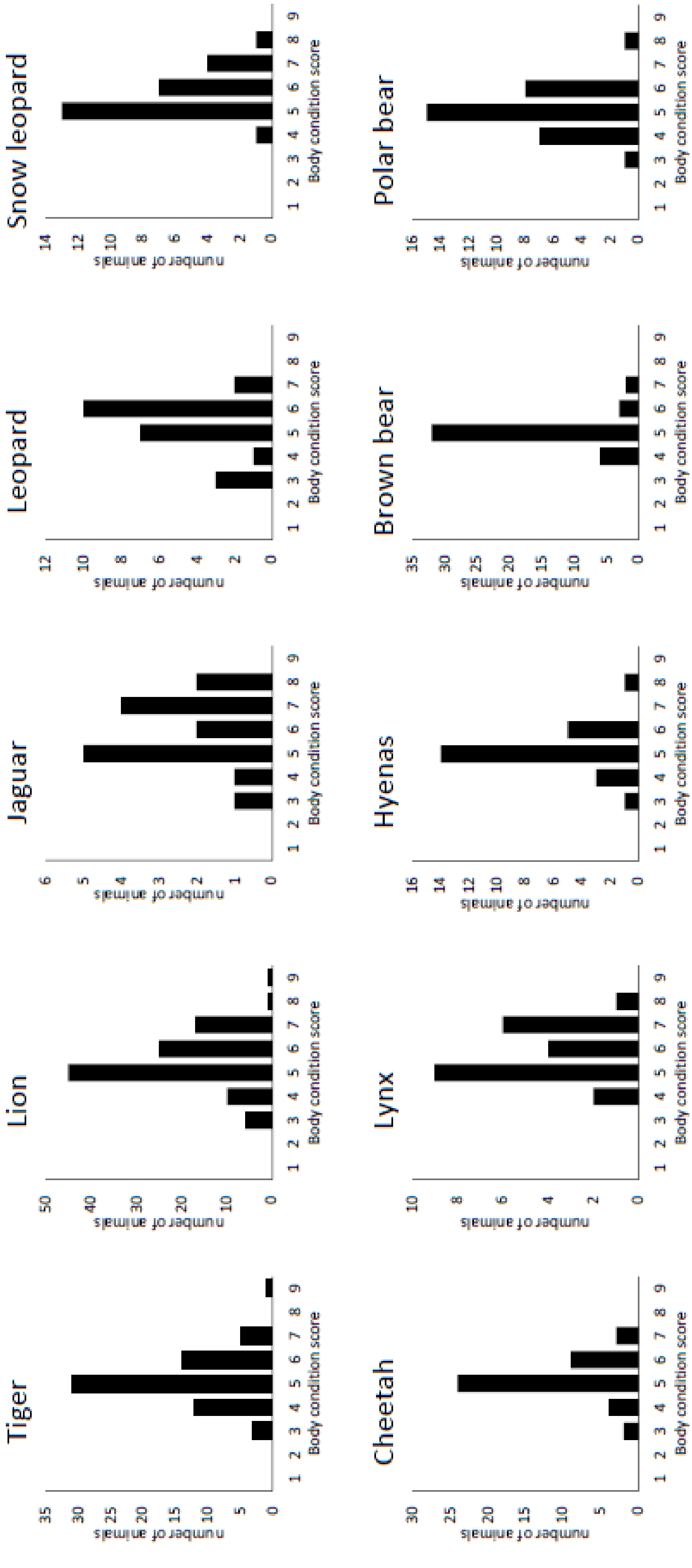

Figure 1. Body condition score distribution in 10 different large carnivores across 44 European zoos.

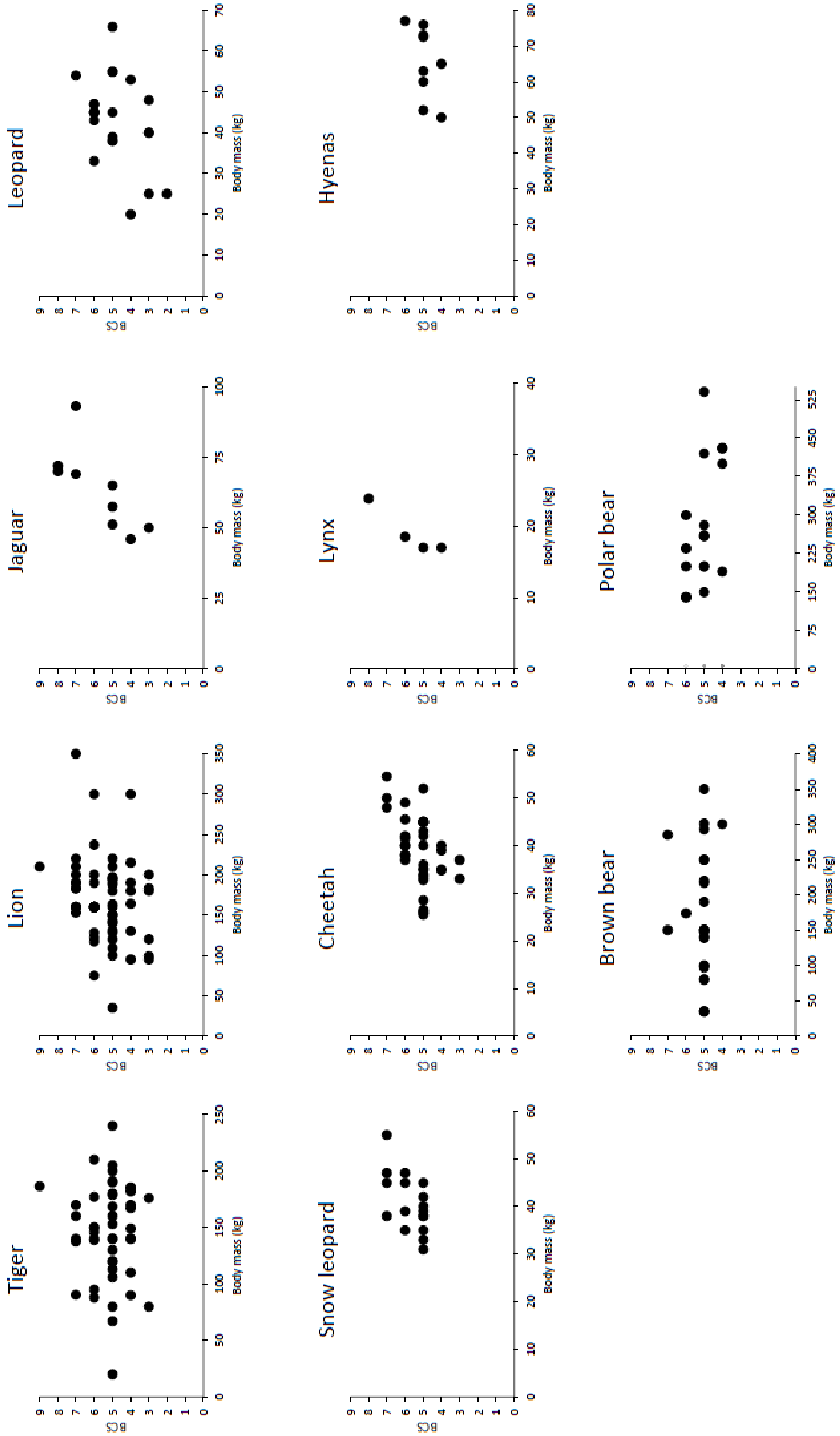

Figure 2. Body condition score in relation to the body mass (kg) in 10 different large carnivores.

except for lions and snow leopards (positive) and tigers (negative trend; Table 2).

Enrichment scores varied between 0 and 24, and were particularly low in cheetahs and particularly high in tigers (Table 1). The enrichment score also did not show a correlation with BCS in most species, expect for an unexpected, positive correlation in lions and leopards (Table 2).

In the general linear model relating to BCS, no clear picture emerged: enclosure size was mainly not significant, except for an unexpected positive association with BCS in jaguars and leopards. The amount fed had, as expected, a positive association with BCS in lions and lynx but an unexpected, negative association in tigers. The enrichment score never showed the expected negative association with BCS, but an unexpected positive association in tigers, leopards and cheetahs (Table 2).

Discussion

The distribution of BCS in this survey suggests that for most species, no particular indication for widespread obesity exists. If the 44 zoos visited in the present study are considered to be representative of the European population, this would translate into the finding that obesity should not be assumed as the general state of large carnivore zoo populations. Evidently, this does not mean that attention to individual animals can be relaxed—it is rather a statement of relevance for general carnivore husbandry. In nearly every species, individual animals with an obese body condition were found, which all represent cases that require, in theory, management adjustments. To the authors' knowledge, no similar surveys exist for carnivores or individual species so there is no basis for detecting a temporal trend in carnivore husbandry in this respect.

Various limitations apply to the present survey. Body condition scores were not corroborated by several independent scorers and were not documented photographically. Body mass estimates were used that may vary distinctively in terms of accuracy. Various different ways of representing enclosure size (e.g. accounting for non-accessible spaces or spaces of limited use) or of quantifying enrichment could have been used. Rather than just recording the average amount of food provided, detailed recording of actual intakes and the nutrient composition of the provided food would have been desirable. While it is unlikely that any of these measures, which were beyond the logistical and financial scope of the present study, would have changed the results in a systematic way, this cannot be claimed with confidence. However, these limitations may well reflect those of zoos applying the same monitoring process. With respect to highly seasonal species—in the context of the present study, the bears—a single time point assessment of body condition cannot be considered adequate; a documentation of seasonal changes in body condition is required.

Under ideal, controlled conditions, a correlation of BCS with an individual's body mass would be expected. Such a correlation should be more distinct in species with a restricted size range and be weaker to non-existent in species where adult individuals have a broad body size range. In the present study, the BCS-body mass correlation was significant or tended towards significance, except for tigers and bears, which supports this concept. The main exception was the leopard, in which the visual impression of a correlation (Figure 2D) was not corroborated statistically (Table 2). Generally, but most particularly in species with a wide body mass range for mature individuals, the BCS is better compared to a body mass index, where the body mass is compared to the actual size of the animal (Labocha et al. 2014). This is because large individuals are not expected to have a higher BCS; instead, individuals that are heavy for their respective size are expected to have a higher BCS. For the present study, establishing a body mass index for the carnivores was not feasible. The general agreement with body mass (estimates) found in the present survey simply corroborates the often-repeated observation that BCS is a useful tool for monitoring. Body condition monitoring, either by weighing or by (photography-supported) BCS, should be part of any modern animal husbandry system.

Surveys such as the present one do not follow an experimental setup, in which cause and effect can be clearly separated. Zoo animal management is a process of constant adjustment, and hence correlations of management determinants with BCS can theoretically yield any outcome, all of which can be conveniently interpreted. If BCS correlates positively with the amount of food provided, for example, this can be interpreted as a simple cause-effect where the majority of the surveyed population is on the feeding regime that triggers these BCS. If BCS correlates negatively with the amount of food provided, this can be interpreted as a population-wide reaction of managers to reduce the amount of food in individuals that appear obese, and to increase the amount of food in individuals that appear too thin. Any absence of a relationship between BCS and the provided food can be interpreted as a mix of both scenarios across the respective population. The same logic applies to the enrichment provided, which might be the cause of or reaction to a specific condition.

Regardless of the findings of a survey such as this, there can be no doubt that the amount of food provided and the amount of physical exercise will have effects on an animal's body condition (Heuberger and Wakshlag 2011; Morrison et al. 2013). Treatment of obesity typically involves reducing caloric intake, either by reducing the amount fed or reducing the energy density in the food provided, or both. In carnivores, providing whole prey as compared to meat-only diets could represent such a reduction in energy density. Due to the effects of more difficult-to-digest parts of whole prey that are subject to bacterial degradation in the hindgut, feeding whole prey can trigger a feeling of satiety (e.g. as suggested in Depauw et al. 2013). By contrast, increasing exercise typically has a less distinct effect on body condition than caloric restriction. In companion animals in which exercise can be easily increased intentionally, such as dogs and horses, exercise appears to be a more promising weight control approach (Butterwick and Hawthorne 1998; German 2006; Moore et al. 2019) than in animals where the incentives for movement can only be given indirectly. This does not mean that exercise-enhancing enrichment should not be given—it is on the contrary one of the hallmarks of professional animal husbandry aimed at providing for many aspects of welfare—but one should not consider it as a major component of a weight management programme.

In this survey, both enclosure size and enrichment were considered as potential factors linked to physical exercise. The overall lack of evident correlations with BCS bespeak the well-known fact that while both factors are important components of welfare, they cannot be equated with the amount of exercise and energy expenditure. Whether an enclosure will trigger activity by its inhabitants will depend on additional factors, such as the specific placement of points of interest (location of feeding, drinking, comfort, exploration) and the provision of enrichment that makes different locations attractive (Powell 1995). The availability of space does not automatically raise an individual's activity level (Galardi et al. 2021), even though Breton and Barrot (2014) described a positive correlation between the size of the enclosure and the total daily distance covered by tigers. These aspects cannot be covered in the simple square metre measurements and enrichment counts used in the present study. The efficacy of enclosures and enrichment needs to be assessed on a case-by-case basis. As a side note, one peculiar finding of the present survey was the large enclosure areas provided to bear species (Table 1). This corresponds to a trend described previously where traditionally small bear enclosures have been replaced increasingly by large enclosures (Kawata 2012). The focus on bears, in this respect, appears mainly triggered by their particularly restricted historical conditions; the appropriateness of similarly large enclosures for other carnivores is evident.

Conclusion

In conclusion, the large carnivore population surveyed in the present study generally showed a 'normal' body condition with only very slight tendencies towards obesity. Body condition corresponded to body mass data in several species, as one would expect. There were no systematic relationships between body condition and enclosure size, amount of food offered or the amount of enrichment provided. In other words, no broad explanations can be given for high or low body condition. Rather, body condition management occurs at the level of the individual facility, where a set of specific measures has a collective effect on the animal.

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References

Adji A.V., Pedersen A.Ø., Agyekum A.K. (2022) Obesity in pet rabbits (*Oryctolagus cuniculus*): A narrative review. *Journal of Exotic Pet Medicine* 41: 30–37. doi:10.1053/j.jepm.2022.02.003

Ahloy-Dallaire J., Espinosa J., Mason G. (2018) Play and optimal welfare: Does play indicate the presence of positive affective states? *Behavioural Processes* 156: 3–15. doi:10.1016/j.beproc.2017.11.011

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

Bray R.E., Edwards M.S. (1999) Body condition scoring of captive (zoo) equids. *Proceedings of the AZA Nutrition Advisory Group Conference*. Columbus, Ohio: AZA Nutrition Advisory Group 3.

Bray R.E., Edwards M.S. (2001) Application of existing domestic animal condition scoring systems for captive zoo animals. *Proceedings of the Conference of the Nutrition Advisory Group* 4: 25–28.

Brereton J.E. (2020) Directions in animal enclosure use studies. *Journal of Zoo and Aquarium Research* 8(1): 1–9. doi:10.19227/jzar.v8i1.330

Breton G., Barrot S. (2014) Influence of enclosure size on the distances covered and paced by captive tigers (*Panthera tigris*). *Applied Animal Behaviour Science* 154: 66–75. doi:10.1016/j.applanim.2014.02.007

Butterwick R.F., Hawthorne A.J. (1998) Advances in dietary management of obesity in dogs and cats. *Journal of Nutrition* 128(12): 2771S–2775S. doi:10.1093/jn/128.12.2771S

Clark A., Silva-Fletcher A., Fox M., Kreuzer M., Clauss M. (2016) Survey of feeding practices, body condition and faeces consistency in captive ant-eating mammals in the UK. *Journal of Zoo and Aquarium Research* 4(4): 183–195. doi:10.19227/jzar.v4i4.207

Clavadetscher I., Bond M.L., Martin L.F., Schiffmann C., Hatt J.M., Clauss M. (2021) Development of an image-based body condition score for giraffes (*Giraffa camelopardalis*) and a comparison of zoo-housed and free-ranging individuals. *Journal of Zoo and Aquarium Research* 9(3): 170–185. doi:10.19227/jzar.v9i3.615

Daigle C.L., Brown J.L., Carlstead K., Pukazhenthi B., Freeman E.W., Snider R.J. (2015) Multi-institutional survey of social, management, husbandry and environmental factors for the SSP African lion *Panthera leo* population: Examining the effects of a breeding moratorium in relation to reproductive success. *International Zoo Yearbook* 49(1): 198–213. doi:10.1111/izy.12073

Das A. (2018) Current trends in feeding and nutrition of zoo animals: A review. *Indian Journal of Animal Nutrition* 35(3): 242–250. doi:10.5958/2231-6744.2018.00038.5

Depauw S., Hesta M., Whitehouse-Tedd K., Vanhaecke L., Verbrugghe A., Janssens G.P.J. (2013) Animal fibre: The forgotten nutrient in strict carnivores? First insights in the cheetah. *Journal of Animal Physiology and Animal Nutrition* 97(1): 146–154. doi:10.1111/j.1439-0396.2011.01252.x

Dierenfeld E., Bush M., Phillips L., Montali R. (1994) Nutrition, food preparation and feeding. In: Tilson R., Brady K., Traylor-Holzer K., Armstrong D. (eds.). *Management and Conservation of Captive Tigers*, Panthera tigris. Apple Valley, Minnesota: Minnesota Zoo, 47–52.

Edwards K.L., Shultz S., Pilgrim M., Walker S.L. (2015) Irregular ovarian activity, body condition and behavioural differences are associated with reproductive success in female eastern black rhinoceros (*Diceros bicornis michaeli*). *General and Comparative Endocrinology* 214: 186–194. doi:10.1016/j.ygcen.2014.07.026

Galardi E.G., Fabbroni M., Rausa F.A., Preziosi R., Brereton J.E., Pastorino G.Q. (2021) An investigation into the behavior, sociality and enclosure use of group-housed lions and tigers. *Journal of Veterinary Medicine and Animal Science* 4(1): 1068.

German A.J. (2006) The growing problem of obesity in dogs and cats. *Journal of Nutrition* 136(7): 1940S–1946S. doi:10.1093/jn/136.7.1940S

Gerstner K., Liesegang A., Hatt J.M., Clauss M., Galeffi C. (2016) Seasonal body mass changes and feed intake in spectacled bears (*Tremarctos ornatus*) at Zurich Zoo. *Journal of Zoo and Aquarium Research* 4(3): 121–126. doi:10.19227/jzar.v4i3.181

Harper E.J., Stack D.M., Watson T.D.G., Moxham G. (2001) Effects of feeding regimens on bodyweight, composition and condition score in cats following ovariohysterectomy. *Journal of Small Animal Practice* 42(9): 433–438. doi:10.1111/j.1748-5827.2001.tb02496.x

Heidegger E.M., von Houwald F., Steck B., Clauss M. (2016) Body condition scoring system for greater one-horned rhino (*Rhinoceros unicornis*): Development and application. *Zoo Biology* 35(5): 432–443.

Heuberger R., Wakshlag J. (2011) The relationship of feeding patterns and obesity in dogs. *Journal of Animal Physiology and Animal Nutrition* 95(1): 98–105. doi:10.1111/j.1439-0396.2010.01024.x

Hickman D.L., Swan M. (2010) Use of a body condition score technique to assess health status in a rat model of polycystic kidney disease. *Journal of the American Association for Laboratory Animal Science* 49(2): 155–159.

Hoy J.M., Murray P.J., Tribe A. (2010) Thirty years later: Enrichment practices for captive mammals. *Zoo Biology* 29(3): 303–316. doi:10.1002/zoo.20254

Kawata K. (2012) Exorcising of a cage: A review of American zoo exhibits, part III. *Der Zoologische Garten* 81(2–3): 132–146. doi:10.1016/j.zoolgart.2012.05.001

Kleinlugtenbelt C.L.M., Burkevica A., Clauss M. (2023a) Large carnivore feeding in European zoos. *Der Zoologische Garten* 91: 9–39. doi:10.53188/zg0012

Kleinlugtenbelt C.L.M., Clauss M., Burkevica A., De Cuyper A. (2023b) Fasted and furious? Considerations on the use of fasting days in large carnivore husbandry. *Journal of Zoo and Aquarium Research* (in press).

Labocha M.K., Schutz H., Hayes J.P. (2014) Which body condition index is best? Oikos 123(1): 111–119. doi:10.1111/j.1600-0706.2013.00755.x

Laflamme D. (1997) Development and validation of a body condition score system for dogs. *Canine Practice* 22(4): 10–15.

Lisi K.J., Barnes T.L., Edwards M.S. (2013) Bear weight management: A diet reduction plan for an obese spectacled bear (*Tremarctos ornatus*). *Journal of Zoo and Aquarium Research* 1(2): 81–84.

Lutz T.A., Woods S.C. (2012) Overview of animal models of obesity. *Current Protocols in Pharmacology* 58(1): 5.61.61–65.61.18. doi:10.1002/0471141755.ph0561s58

Meehan C.L., Mench J.A. (2007) The challenge of challenge: Can problem solving opportunities enhance animal welfare? *Applied Animal Behaviour Science* 102(3–4): 246–261.

Mellen J., Sevenich MacPhee M. (2001) Philosophy of environmental enrichment: Past, present, and future. *Zoo Biology* 20(3): 211–226. doi:10.1002/zoo.1021

Mellor E.L., Cuthill I.C., Schwitzer C., Mason G.J., Mendl M. (2020) Large lemurs: Ecological, demographic and environmental risk factors for weight gain in captivity. *Animals* 10(8): 1443. doi:10.3390/ani10081443

Moore J.L., Siciliano P.D., Pratt-Phillips S.E. (2019) Effects of diet versus exercise on morphometric measurements, blood hormone concentrations, and oral sugar test response in obese horses. *Journal of Equine Veterinary Science* 78: 38–45. doi:10.1016/j.jevs.2019.03.214

Morfeld K.A., Meehan C.L., Hogan J.N., Brown J.L. (2016) Assessment of body condition in African (*Loxodonta africana*) and Asian (*Elephas maximus*) elephants in North American zoos and management practices associated with high body condition scores. *PLoS ONE* 11(7): e0155146. doi:10.1371/journal.pone.0155146

Morrison R., Penpraze V., Beber A., Reilly J.J., Yam P.S. (2013) Associations between obesity and physical activity in dogs: A preliminary investigation. *Journal of Small Animal Practice* 54(11): 570–574. doi:10.1111/jsap.12142

Powell D.M. (1995) Preliminary evaluation of environmental enrichment techniques for African lions (*Panthera leo*). *Animal Welfare* 4(4): 361–370. doi:10.1017/S0962728600018054

R Core Team (2020) *R: A Language and Environment for Statistical Computing*. version 3.6.3. Vienna, Austria: R Foundation for Statistical Computing. http://www.R-project.org/.

Reppert A., Treiber K., Ward A. (2011) Body condition scoring in cheetah (*Acinonyx jubatus*) advancements in methodology and visual tools for assessment. *Proceedings of the Ninth Conference on Zoo and Wildlife Nutrition*. Kansas City , Missouri: AZA Nutrition Advisory Group.

Schiffmann C., Clauss M., Hoby S., Hatt J.M. (2017) Visual body condition scoring in zoo animals – composite, algorithm and overview approaches. *Journal of Zoo and Aquarium Research* 5(1): 1–10. doi:10.19227/jzar.v5i1.252

Schiffmann C., Clauss M., Hoby S., Codron D., Hatt J.M. (2019a) Body Condition Scores (BCS) in European zoo elephants' (*Loxodonta africana* and *Elephas maximus*) lifetimes – A longitudinal analysis. *Journal of Zoo and Aquarium Research* 7(2): 74–86. doi:10.19227/jzar.v7i2.375

Schiffmann C., Clauss M., Hoby S., Hatt J.M. (2019b) Weigh and see – Body mass recordings versus body condition scoring (BCS) in zoo elephants (*Loxodonta africana* and *Elephas maximus)*. *Zoo Biology* 39(2): 97–108. doi:10.1002/zoo.21525

Smit M., Corner-Thomas R.A., Weidgraaf K., Thomas D.G. (2022) Association of age and body condition with physical activity of domestic cats (*Felis catus*). *Applied Animal Behaviour Science* 248: 105584. doi:10.1016/j.applanim.2022.105584

Szokalski M.S., Litchfield C.A., Foster W.K. (2012) Enrichment for captive tigers (*Panthera tigris*): Current knowledge and future directions. *Applied Animal Behaviour Science* 139(1–2): 1–9. doi:10.1016/j.applanim.2012.02.021

Warren B.S., Wakshlag J.J., Maley M., Farrell T.J., Struble A.M., Panasevich M.R., Wells M.T. (2011) Use of pedometers to measure the relationship of dog walking to body condition score in obese and non-obese dogs. *British Journal of Nutrition* 106(1): 85–89. doi:10.1017/S000711451100181