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Feeding regimen and growth comparison in two related African painted dog *Lycaon pictus* litters

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Abstract

There is a lack of published studies on feeding regimens and growth in zoological painted dog *Lycaon pictus* populations, and hence, a gap in understanding potential relationships between the two. Here we present a case study evaluating the influence of two feeding protocols (ad libitum and controlled feed) on morphometric measurements, litter, age, and the interaction between litter and age, of two related painted dog litters (i.e., same sire, sibling dams). Beginning at approximately 8 weeks of age, one litter was fed ad libitum (i.e., food freely available), and the other fed at regular time intervals (i.e., controlled). Ten physical measurements were obtained during 10 and 14-week pup wellness checks. Morphometric measurements between litters were comparable for body length, ear height, head circumference, and muzzle length at each age. Conversely, hind leg/body length ratios, front and hind leg/body length differentials, and mean body mass differed significantly between litters at each age. Although limited by a small sample size, the findings of our opportunistic study indicate that the relationships among feeding frequency, food items, and growth/development require further research, as altered morphometrics of captive animals to be released into the wild, or starvation conditions in free-ranging packs during critical growth periods, could have consequences for individuals and packs alike. More information relating to this topic is needed to improve husbandry practices for individuals in zoological collections, as well as inform management and conservation decisions affecting free-ranging populations.

Background

As zoos and captive breeding programs provide a source of genetic stock for wild populations, it is important that captive individuals destined to be returned to the wild receive proper care so they accurately represent their wild counterparts. Zoological institutions attempt to maintain genetic diversity (Marsden et al. 2013), however, captivity has been demonstrated to alter morphology in carnivores (Hartstone-Rose et al. 2014; Curtis et al. 2018) and other groups (Dierenfeld 1997; O'Regan and Kitchener 2005). This is problematic as altered morphology of individuals targeted for release or reintroduction could prove detrimental for both individuals and populations in ways that are not fully understood.

Early dietary management of captive animals attempted to replicate wild diets but focused more on short-term goals rather than long-term health, growth, and reproduction (Dierenfeld 1997). Advances in nutritional knowledge and recommendations that zoological diets be developed according to individual and species nutritional requirements, feeding ecology, and natural history (AZA Canid TAG 2012, p. 28) have improved feeding protocols (Dierenfeld 1997; Irwin et al. 2013), yet implementing standardised dietary requirements and feeding protocols among zoological institutions and species is difficult due to varying needs of individuals within a species and food item choice that is often constrained by funding, practical considerations such as convenience, and an institution's level of comfort and familiarity (Hill et al. 2019).

Quality nutrition is vital, but it is important to consider not only the type of food, but also the frequency of feeding and food presentation. When African lions *Panthera leo* were switched from routine feeding schedules to a fast/gorge schedule, the lions lost weight (resulting in weights comparable with those of wild lions) and their digestibility of fat and protein increased (Altman et al. 2005). Similar changes have been observed in reptiles. Boas *Boa constrictor* fed 20% of their body mass on a bi-weekly basis grew larger and faster than a group fed 10% of their body mass on a weekly basis (Hill et al. 2019). It is unclear how, or if, the larger and faster growth affected the boas in the short or long-term, but these case studies lend support to the potential influence of feeding strategies (e.g., frequency and volume) on the fitness and growth of various species (Hill et al. 2019).

Developing optimal feeding protocols for carnivores is challenging (Altman et al. 2005), and many institutions learn through trial and error based on recommendations from veterinary and nutritional professionals (AZA Canid TAG 2012). The implications are especially important for species such as endangered African painted dogs *Lycaon pictus* where knowledge gaps regarding relationships between diet, feeding protocols, and growth still exist. Painted dogs, also known as African wild dogs, are one of Africa's most endangered carnivores (Range Wide Conservation Program for Cheetah and African Wild Dogs 2020; Woodroffe and Sillero-Zubiri 2020). Cooperative hunters and breeders, each pack member is crucial to foraging activities that are vital for pack survival and raising young (Courchamp and Macdonald 2001; Creel 2001; Courchamp et al. 2002). They hunt multiple times a day (i.e., dawn, dusk, full moon; Rasmussen and Macdonald 2012; Rasmussen et al. 2008), and during denning season, energetic costs are up to 30% higher in packs ≤5, and 15% higher in larger packs (Rasmussen et al. 2008). Consequently, there is pressure to rapidly raise pups and become nomadic again. Such pressure would have led to evolutionary adaptations that include rapid pup leg length growth to facilitate nomadism, and precocious optimal adult anatomical proportions needed to successfully chase and capture prey. This precocious growth is seen in other species with high energy expenditure and foraging costs (Rizzolo et al. 2015), and it is postulated that most canid species have evolved similar adaptations in their growth rates and body proportions (Hildebrand 1952).

In North American captive facilities, most painted dogs are fed a "nutritionally complete raw meat-based" diet on a daily basis (AZA Canid TAG 2012, p. 30). Supplemental items such as bones, rabbits *Oryctolagus cuniculus*, mice *Mus musculus*, and deer *Odocoileus virginianus* carcasses are also offered (AZA Canid TAG 2012; Cloutier and Packard 2014). No specific feeding protocols are provided for neonates as it is expected that nutritional needs are met by nursing females (AZA Canid TAG 2012). Bell et al. (2012), in their study on cheetahs *Acinonyx jubatus*, noted that feeding protocols differed between North America and other parts of the world, but that many facilities use ad libitum feeding (i.e., food is freely available rather than offered at specific times) with the assumption that animals will self-regulate to obtain adequate nutrition.

Lack of nutritional support for appropriate growth at critical stages could adversely impact an individual's overall growth as an adult, and thus their fitness and survival in both captivity and in the wild. Empirical studies on painted dog feeding and growth in zoos could facilitate a greater understanding of their growth needs. One institution's comparison of the influence of hand feeding and group feeding protocols on the weight and morphometrics of female siblings from successive litters found that the pups that were started on meat at six weeks of age and fed as a pack weighed more and had longer body, front, and hind limb measurements than individuals not fed this way (Gorsuch and Kelly, unpublished data). Here, the potential influence of two feeding protocols (ad libitum and controlled feed) on the morphometrics and weights of two related litters of painted dogs was investigated. The goal was identify optimal conditions for raising painted dogs in captivity for overall health and fitness, as well as for releasing individuals into the wild, as has been done for other species (Tutin et al. 2001; Britt et al. 2004; Sanz and Grajal 2008).

Action

The study site was the Endangered Wolf Center (EWC), located in eastern Missouri. EWC's landscape consists of old growth hardwood forest and rolling hills, with sycamore, cottonwood, hickory, and oak as some of the dominant tree species. Temperatures range from below freezing during winter to over 32° C (90° F) in the hot, dry summer season (Decker 2020). Mean annual precipitation averages around 9.14 cm (Decker 2020).

Litters

Two litters of painted dogs were born at EWC in 2018: Litter A (13 puppies; 8 females, 5 males) was born on 16 November, and Litter B (10 puppies; 5 females, 5 males) was born on 20 November. The sire of both litters was born on 14 September 2012, and the sibling dams were born on 23 June 2014. All three adults lived together within the same enclosure (Figure 1). Litter A's dam went into labour first and selected the den on the right side of the enclosure (Figure 1). Litter B's dam was then contained on the left side (Figure 1), where she gave birth four days later. Aggression between the dams prevented reintroduction of all individuals into one cohesive pack. In lieu of one pack, the sire was shifted between enclosures on average every other day to encourage social interaction between both females and their litters.

Enclosures

The painted dog exhibit consisted of two adjoining enclosures separated by a chain link fence and two access gates (Figure 1). The front of Litter A's enclosure faced an access road, with the remaining two sides facing Mexican gray wolf *Canis lupus baileyi* and maned wolf *Chrysocyon brachyurus* enclosures. Litter A's enclosure included a tunnel, hill, trees, and fallen logs. The front and a portion of one side of Litter B's enclosure faced the access road, and the rear faced a Mexican gray wolf enclosure. It included a tree, pond, and fallen logs. Both enclosures contained sheds/dens and holding areas (represented by two adjacent rectangles in Figure 1). Substrate consisted of varying degrees of bare ground, grass, leaf litter, and snow throughout the study period.

Pre-Study Feeding Regimen

Pups were weaned around three weeks of age when adults began regurgitating food for them. From the time of weaning until the study period began at approximately 8 weeks of age, both litters were fed the same amount of food per puppy per day. The formula, metabolizable energy (ME) (kcal/d) = 130 x body weight (BW) (kg) ^ 0.75, was used as a general reference when determining the amount of food needed per pup (Burger 1995). This resulted in both litters being fed based on 5-7% of their estimated body weight (kg) per day.

Both litters were fed the same diet that consisted of a precalculated combination of Mazuri Exotic Canine Dry Dog Food (also referred to as chow) and meat items. Meat items consisted of the following: 80% Nebraska Classic Canine diet, 17% whole prey items cut into pieces (primarily rabbit and guinea pig *Cavia porcellus*, but venison, bison, beef, and pork offered occasionally as well), and 3% beef fat cut into bite-sized cubes. The meat item ratios were maintained throughout the study for both litters. Initially, Litter A (13 pups) was offered a daily total of approximately

3600g of meat items and 900g of chow. Litter B (10 pups) received approximately 2300g of meat items and 900g of chow daily.

All food (including carcasses, bones, and any food not consumed) was weighed and recorded. Food requirements were calculated based on individual pup needs but fed at the aggregate litter level, so exact volumes consumed by individual pups at each feeding are unknown. Appetite consumption (i.e., voracity) and outside temperatures (which ranged from -21 to 22°C during the study period) were also factored into their feeding regimens as needed. An increase in voracity (or individual pups begging or searching for more food), for example, resulted in an evaluation of the pups' weight, outside temperatures, and time since the last diet increase. On days with extreme temperatures (temperatures below -18°C), additional food per pup (approximately 100g-300g) was given per day to offset excess body heat loss.

Litter A feeding regimen (ad libitum) during study period

Litter A had access to food throughout the day via training sessions and a food tray that held both meat items and chow and was freely accessible to the pups. Training sessions were conducted at 09:30 and 14:30, with keepers offering meat items during these sessions. Any leftover meat items from training sessions were weighed, recorded, and added to the chow on the food tray. Some pups chose not to approach the keepers during the training sessions, but would eat meat from the tray once it was added. If all food items on the tray were consumed before the afternoon training session, more chow and meat were added to the tray. Keepers also replenished the food tray with chow and meat items for the overnight. Any food items that remained in the morning were weighed, recorded, and discarded.

Litter B feeding regimen (controlled) during study period

Litter B continued following the pre-study formula of calculating daily food requirements (per pup) based on 5-7% of their estimated body weight. Meat items were offered at both the morning and afternoon training sessions, with their total meat for the day divided between these two sessions. Any leftover meat items from the morning training session were added to the afternoon training session as meat items were weighed out per pup per day. If pups did not consume all meat items offered that day, they were not given additional food. A total of 0.908kg of chow was given per day after the morning training session, resulting in a finite amount of food that was offered per pup per day.

Data Collection

The Endangered Wolf Center's IACUC Committee reviews all proposed research that may be considered invasive. Pup health and welfare examinations included an overall assessment of the pup's health, examination of body condition and growth, weight, and administration of vaccinations, dewormers, and ectoparasite prevention medication. The IACUC Committee deemed this research non-invasive due to researchers working with the EWC team to obtain measurements during the time veterinarians were giving the pups their required scheduled vaccinations and health checks.

Wellness checks

Three wellness checks were performed when the pups were approximately 7, 10, and 14 weeks of age. Pups were weighed at each wellness check and morphometric measurements were recorded at 10 (Litter A was 71 days old, Litter B was 75 days

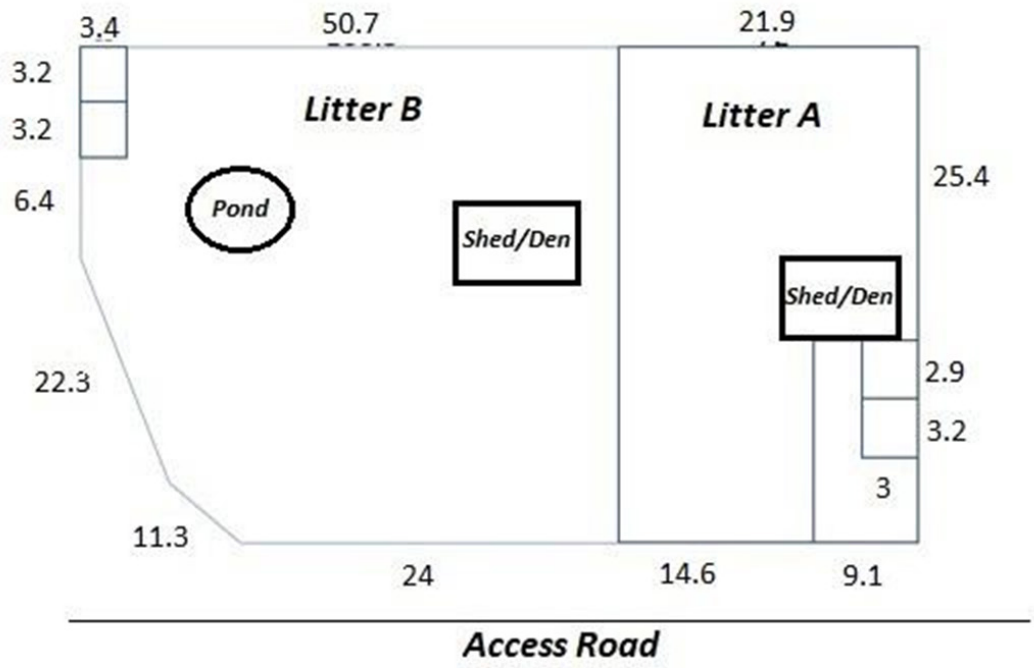

Figure 1. Diagram of the Endangered Wolf Center's painted dog enclosures with approximate measurements (in metres). Features within the enclosures are representative and not to scale. Diagram courtesy of Erin Connett.

old) and 14 weeks (Litter A was 99 days old, Litter B was 103 days old). After containing the adults, EWC staff captured each litter separately, placing multiple individuals from the same litter together in portable kennel crates. Crates were transported to a work area in a large, quiet building where the wellness checks (physical exam, weight, vaccinations) and morphometric measurements were completed. The work area was divided into two sections (one for Litter A, one for Litter B) prior to the arrival of the pups to decrease stress and separation and handling times.

Morphometric measurements

Prior to the pups arriving, instructions and reference measurement charts (Figure 2) were provided to participants who obtained morphometric measurements (Table 1). Practice measurements were taken and compared amongst those measuring to ensure consistency among measurements. Two handlers manually restrained each pup while one person took the measurements using a measuring tape. A cloth was placed over each pup's eyes to minimise stimulation during measurements. Each measurement was rounded to the nearest centimetre (cm) for efficiency and verbally relayed to, and confirmed by, an assigned data recorder for documentation. Once measured, pups were placed in carriers with their littermates in a quiet area. All pups were transported back to their enclosures as soon as possible following measurement of the last pup.

Ten morphometric measurements were obtained for each pup (Table 1). Body length and front and hind limb measurements were selected for their distinct and identifiable measurement points. Ear, muzzle, and head circumference measurements were easily obtained, but did not possess specific morphological landmarks (e.g., elbow). The following metrics were included in analysis: BL, ER, HC, ML, FL/BL, HL/BL, and FL-HL/BL (Table 1 and Table 2).

Due to our small sample size, the Shapiro-Wilk test was used to assess morphometric measurements for normality, and t-tests

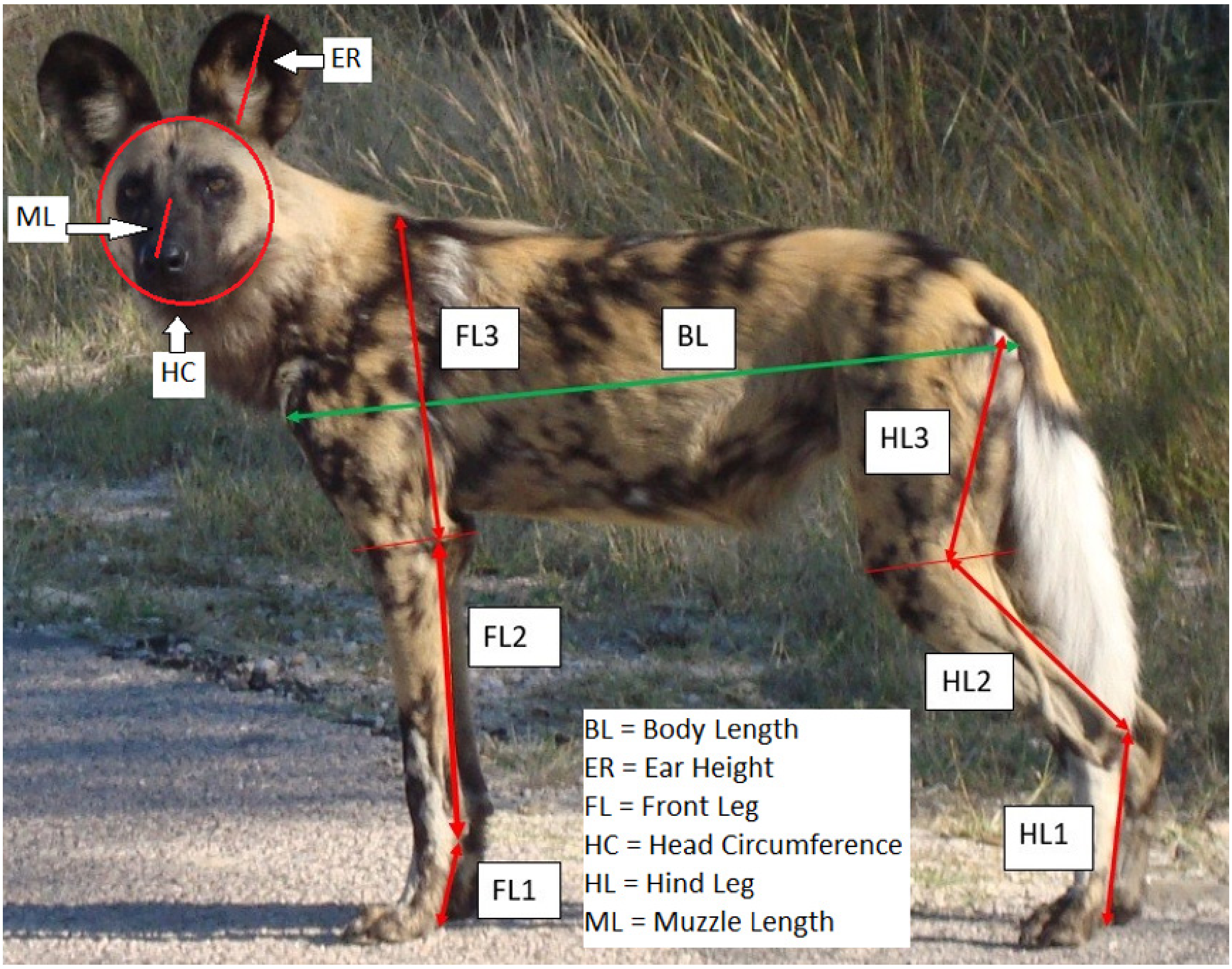

Figure 2. Morphometric measurements obtained for each painted dog pup during 10 and 14-week wellness checks at the Endangered Wolf Center. Image courtesy of Greg Rasmussen.

Table 1. Definitions of morphometric measurements obtained for each painted dog pup at 10 and 14-week wellness checks at the Endangered Wolf Center.

Abbreviation	Definition	Points of Measurement
BL	Body Length	Point of front shoulder to sacroiliac process under base of tail
FL1	Front Leg Measurement 1	Ventral surface of paw pad to rear carpal joint
FL2	Front Leg Measurement 2	Rear carpal joint to back of elbow joint
FL3	Front Leg Measurement 3	Back of elbow joint to dorsal point of scapula
HL1	Hind Leg Measurement 1	Ventral surface of paw pad to rear of hock
HL2	Hind Leg Measurement 2	Rear of hock to mid-stifle joint
HL3	Hind Leg Measurement 3	Mid-stifle joint to tip of sacroiliac process
ER	Ear Height	Middle of base of front of ear to highest point of ear
HC	Head Circumference	Start and stop at midpoint between ears following base of ears and mandible
ML	Muzzle Length	Base of muzzle near eyes to tip of nose

were used to evaluate whether there was an effect of sex on growth (i.e., a difference in measurements and proportions between males and females). Mixed effects models were run to test whether each morphometric measurement, the response variables, were related to predictor variables, litter (and hence, feeding regimen), age, and the interaction between litter and age, to indicate differences between litters in the growth of pups over time. Separate models were created for each of the metrics listed above. TFL and THL (Table 2) were calculated for use in the differential models; separate analyses were not run for these two items. A relationship between each pup's measurements over time was assumed. If, for example, a pup was larger at birth, it would remain so over time. Pups were thus treated as a random effect, whereas time (week) was treated as a fixed effect. All analyses were conducted using IBM SPSS Statistics 26 (α=0.05).

Consequences

No effect of sex on growth (t= -1.560, df=56.563, P=0.124) was identified, therefore, sex was not included in the mixed effects models. Measurements for body length (BL), ear height (ER), head circumference (HC), and muzzle length (ML) were comparable between the litters (Table 3). As expected, measurements increased significantly between wellness checks as pups grew (Table 3). Table 3. Comparison of morphometric means and weights between painted dog Litter A (ad libitum) and Litter B (controlled feed) at 10 and 14-week pup wellness checks and results of the fixed effects from the mixed effects models.

Front leg/body length (FL/BL) ratios were not significantly affected by litter (i.e., feeding regimen), age, or the interaction of litter and age (Table 3). Front legs of pups were consistent

Table 2. Morphometric measurement definitions for the three response variables used in painted dog pup growth analyses.

Abbreviation	Definition	Points of Measurement
TFL	Total Front Leg	sum of FL1, FL2, and FL3
THL	Total Hind Leg	sum of HL1, HL2, and HL3
FL-HL/BL	Difference in Leg Length/Body Length Differential	difference between TFL and THL divided by BL
FL/BL	Front Leg/Body Length Differential	front leg divided by body length
HL/BL	Hind Leg/Body Length Differential	hind leg divided by body length

Table 3. Body measurements.

	Age week	Litter A Measurement Mean (cm) (ad libitum)	Min/Max (cm)	Std. error for means	Litter B Measurement Mean (cm) (ad libitum)	Min/Max (cm)	Std. Error for Means	Effect of Litter	Effect of Age	Effect of Litter and Age Interaction
Body length	10	38.15	23/45	0.878	37.3	32.5/41	1.001	$F_{1.639,}$ df=21, P=0.214	$F_{212.953,}$ df=21, P<0.001	$F_{0.705,}$ df=21, P=0.410
	14	49.04	43/53		47.00	43.5/49				
Ear height	10	9.19	8.25/10	0.190	8.98	8/10	0.216	$F_{0.019,}$ df=21, P=0.892	$F_{115.790,}$ df=21, P<0.001	$F_{1.179,}$ df=21, P=0.290
	14	10.85	10/11.5		11.00	10/12.5				
Head circumference	10	30.09	28/33	0.347	29.80	28.5/31.5	0.396	$F_{1.675,}$ df=21, P=0.210	$F_{1.675,}$ df=21, P=0.210	$F_{1.165,}$ df=21, P=0.293
	14	35.58	34/37.5		34.70	32/37				
Muzzle length	10	13.12	12/15	0.282	12.60	11.5/14	0.321	$F_{0.770,}$ df=21, P=0.390	$F_{49.060,}$ df=21, P<0.001	$F_{0.693,}$ df=21, P=0.415
	14	14.77	13/16		14.70	13/18				
Front leg/ Body length	10	0.974	0.848/1.109	0.020	0.967	0.902/1.046	0.023	$F_{0.006,}$ df=21, P=0.938	$F_{0.342,}$ df=21, P=0.565	$F_{0.183,}$ df=21, P=0.673
	14	0.954			0.964	0.906/1.106				
Hind leg/Body length	10	0.990	0.775/1.138	0.024	0.969	0.902/1.076	0.027	$F_{1.710,}$ df=21, P=0.205	$F_{0.001,}$ df=21, P=0.972	$F_{9.001,}$ df=21, P=0.007
	14	0.929	0.839/1.058		1.029	0.958/1.103				
Front leg - Hind leg/Body length	10	-0.016	-0.156/0	0.018	-0.002	-0.039/0	0.020	$F_{3.510,}$ df=21, P=0.075	$F_{0.330,}$ df=21, P=0.572	$F_{7.911,}$ df=21, P=0.010
	14	0.025	-0.048/0		-0.064	-0.195/0.010				
Weight (kg)	7	3.79	3.44/4.17	0.376	3.56	2.90/4.08	0.429	$F_{11.510,}$ df=21, P=0.003	$F_{1529.660,}$ df=42, P<0.001	$F_{29.642,}$ df=42, P<0.001
	10	5.98	4.71/6.71		5.77	4.71/6.62				
	14	10.98	9.52/12.06		9.19	7.52/11.06				

in proportion to their body across litter and time (Table 3). In contrast, hind leg/body length growth, and differences between limb lengths/body lengths, were significantly different between the packs (Table 3; Figure 3 and 4). This presented as Litter B's hind legs being longer than their front legs when compared to Litter A. In addition, litter, age, and the interaction of litter and age, all had significant effects on differences in mean weights (Table 3).

This case study investigated feeding regimens and growth between two closely related captive painted dog litters at a North American conservation facility. Painted dog pup morphometric measurements were reported in two previous publications, although there were only two potentially similar measurements between our study and the two published studies that may offer any comparison. Thomas et al. (2006) measured pinna length, comparable to what was labelled as "ear height" in this study, and Kenny et al. (2007) measured height, defined as the top of the scapula to the bottom of the foot when placed flat. The latter may be similar to this study's total front leg measurement, but without knowing more specific measurement points, this remains unclear. Ear height means and significant differences in measurements over time for EWC pups were consistent with Thomas et al. (2006) pinna length measurements, however, due to lack of published data on overall growth and body and limb length ratios in captive and free-ranging painted dogs, it is unknown if measurements from Thomas et al. (2006), Kenny et al. (2007), and our study are representative of typical pup growth and/or comparable to other individuals or populations.

Diet and appropriate growth are important for the overall health of captive animals, but particularly relevant for captive individuals targeted for reintroduction and free-ranging populations stressed by human activity. Studies have shown that captivity played a role in altering morphology in other species (Dierenfeld 1997; O'Regan and Kitchener 2005; Hartstone-Rose et al. 2014; Curtis et al. 2018). While morphological diversity is naturally present among wild and domesticated canids, the conformation variations do not always lend themselves to maximum energetic efficiency (Bryce and Williams 2017). For example, Bryce and Williams (2017) observed that three northern dog breeds (Siberian huskies, Alaskan malamutes, and Samoyeds) had lower locomotor costs when trotting compared to other gaits (i.e., walk, gallop), similar to their wild conspecifics, wolves. Other similarities between northern dog breeds and wolves are that their hind limbs are located closer to their centre of mass, allowing for a more upright stance and relatively flat toplines when running, promoting energy efficiency (Bryce and Williams 2017). As cursorial predators that travel long distances, painted dogs share similar conformations. This supports

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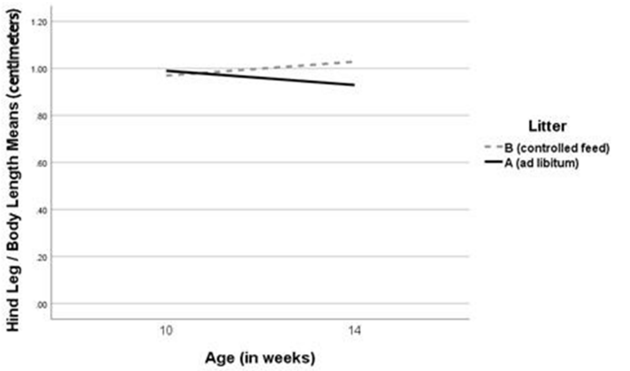

Figure 3. Interaction plot comparing painted dog pup means of HL/BL (ratio of THL [total hind leg] divided by BL [body length]) between Litter A (ad libitum) and Litter B (controlled feed) at 10 and 14-week pup wellness checks.

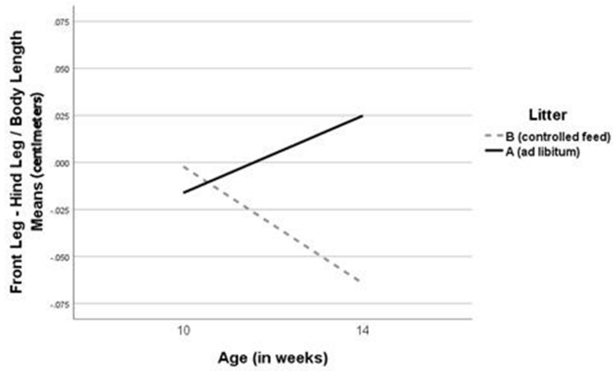

Figure 4. Interaction plot comparing painted dog pup means of FL-HL/BL (difference between TFL [total front leg] and THL [total hind leg] divided by BL [body length]) between Litter A (ad libitum) and Litter B (controlled feed) at 10 and 14-week pup wellness checks.

the contention that changes in front or hind limb length may affect their center of mass and increase energetic costs, potentially decreasing fitness and survival (Kilbourne and Hoffman 2015; Bryce and Williams 2017). Morphological change of this type must be taken into consideration when caring for these animals, particularly if morphological differences are retained as adults.

Bell et al. (2012) suggested that individuals fed ad libitum would show higher growth, demonstrated by longer body and limb length in cheetahs. Litter A exhibited larger body lengths; however, the difference was not significant. In addition, although Litter A weighed more than Litter B, this was consistent for all three wellness checks, even before feeding differences were implemented. This suggests that weight differences may not necessarily be attributed to feeding regimen. Both litters demonstrated body and limb length differences over time, yet Litter B's hind legs were statistically significantly longer relative to their body and front limb length, particularly at the 14-week pup wellness check. This changed their conformation in comparison to Litter A by shifting their centre of mass to a more forward and down, rather than upright, position, altering their stance and running gaits. The difference was less pronounced at the 10-week wellness check, so it is unclear if this difference was influenced by feeding regimen. It is also unknown if or how this morphometric alteration will affect them as adults, but this change in conformation could be detrimental to captive animals, captive animals released into the wild, and free-ranging populations that are not able to adequately feed pups due to habitat alterations or human disturbance.

It is uncertain if the morphological differences observed between litters can be attributed to feeding regimen, level of activity of each litter, genetics, and/or other unknown factors, but does highlight the need for further consideration of factors such as individual/pack differences and/or enclosure guidelines. For example, Litter A's measurements were slightly larger overall, and while both litters engaged in play behaviour that included running and wrestling, Litter B was generally more active based on keeper and intern observations. The difference in engagement in these locomotive behaviours as related to foraging may potentially illustrate the connection between predatory behaviour and morphology referenced by Martín-Serra et al. (2016) in that limb/body length ratios may be affected by activity levels and feeding protocols. This may offer one potential explanation for the difference in limb ratios between these two litters.

One male producing simultaneous litters with two sisters (who were comparable in physical size) offered an opportunity to collect information on the potential relationship between feeding regimen and growth of painted dogs at a single conservation facility. The nature of this opportunity reduced influential factors such as genetic and environmental variation, but did not eliminate effects of these and other internal or external factors. This case study does, however, indicate a need for more information relating to diet, feeding regimen, and growth in both captive and free-ranging painted dog populations. For instance, free-ranging painted dogs typically hunt at dawn and dusk, regurgitating varying amounts of various prey items for pups after each hunt (Courchamp et al. 2002; Rasmussen et al. 2008), whereas feeding schedules for captive pups may vary across institutions, but the amount and type of food offered may remain consistent. Our study also supports the notion of instituting a standardised approach for obtaining growth measurements, not only to allow for replication across studies and institutions, but to also gain more insight into painted dog growth and development. Wellness checks may be an ideal time to obtain these physical measurements, but if not possible, rough measurements can also be ascertained noninvasively via photographs (Rasmussen et al. 2021) taken by institutional staff, volunteers, and visitors, or posted on social media (Cloutier et al. 2020). Additional studies are strongly encouraged to continue to improve husbandry practices for ex-situ populations, and ultimately, facilitate more effective conservation efforts for free-ranging populations.

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