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Husbandry, feeding, veterinary and reproductive management in maned wolves (*Chrysocyon brachyurus*) in zoological facilities in Europe, Australia and North America

Haltung, Fütterung, tiermedizinisches und Fortpflanzungsmanagement von Mähnenwölfen (*Chrysocyon brachyurus*) in europäischen, australischen und nordamerikanischen Zoos

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Abstract

Historically, the zoo-kept maned wolf (*Chrysocyon brachyurus*) population has suffered from poor reproductive success and a high prevalence of cystinuria, which was attributed to the feeding of a carnivore diet to these generalist omnivores. A multi-institutional survey of zoos (*n*=62) in Europe, North America and Australia was conducted to evaluate relationships between husbandry, feeding, reproduction and medical management. Data was collected on 169 animals, 81 females, 86 males and two of unknown sex, ranging in age from 1 month to 16 years. This study indicates that factors relevant to reproductive success include paternal parenting behaviour, restricting access to indoor enclosures, the presence of previous offspring during the breeding season and insufficient monitoring during the reproductive period. Health concerns most frequently reported over the past 15 years were poor body condition, cystinuria and nephritis. Diets varied considerably, with North American zoo diets typically including Mazuri®

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Maned Wolf Diet or commercial dog foods, and European and Australian zoo diets primarily consisting of small prey animals with varying additions of fruit and vegetables. The most notable difference between all zoo diets and the diet of free-ranging maned wolves was a lack of grasses and *Solanum* fruits in zoo diets. The findings in this study suggest that zoo diets would mirror the diets of free-ranging animals more effectively if they contained equal proportions of animal and plant material, which could potentially also help to address poor body condition and cystinuria. To address the poor reproductive success, further research, including close monitoring during the reproductive period, is warranted.

Keywords: Maned wolf, *Chrysocyon brachyurus*, feeding, husbandry, reproduction, diseases

Introduction

Maned wolves (*Chrysocyon brachyurus*) have been kept in zoos in Europe and the United States since the 1960s (Dmoch, 2007). In the United States, the Maned Wolf Species Survival Plan (MWSSP) manages the captive population of maned wolves and works together with similar programmes in other regions of the world, such as the European Ex-situ Programme (EEP), to sustain genetic diversity and improve the collective understanding of maned wolf husbandry (Songsasen & Rodden, 2010). There are currently 66 zoological institutions in Europe housing maned wolves, 33 in North America and 7 in Australia (Holland, 2020). The total population has been increasing, but the numbers have been stagnating in recent years (Fig. 1). The main challenge of maned wolf husbandry is poor reproduction, which is reflect-

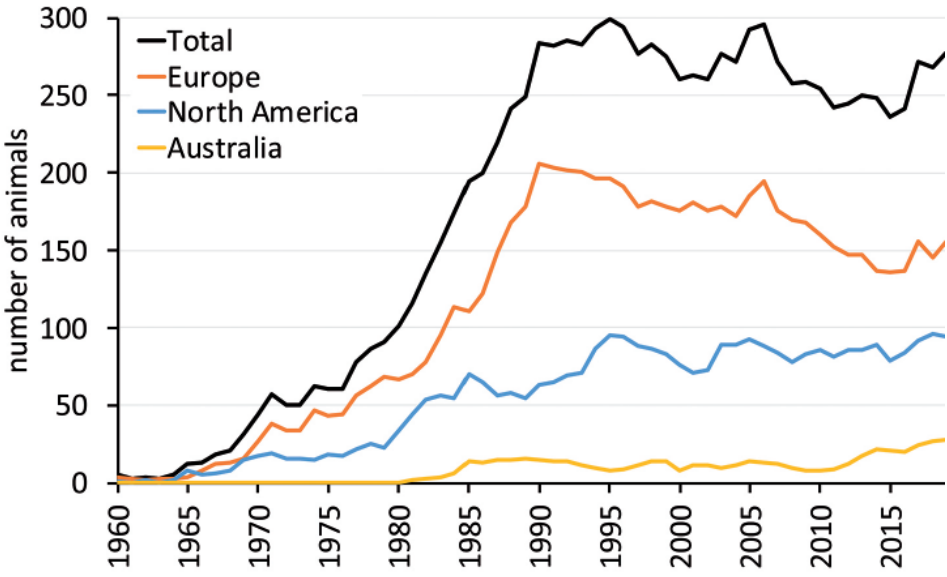

Fig. 1: Population development of the total global population of zoo-kept maned wolves including Asia, South America, North America, Europe and Australia, as well as the individual population development in North America, Europe and Australia (Holland 2020).

ed in the global as well as regional population pyramids, which lack a broad basis of neonates and juveniles, possibly except for the European population (Fig. 2). Additional challenges comprise appropriate feeding regimes and some health issues, especially cystinuria (Songsasen & Rodden, 2010).

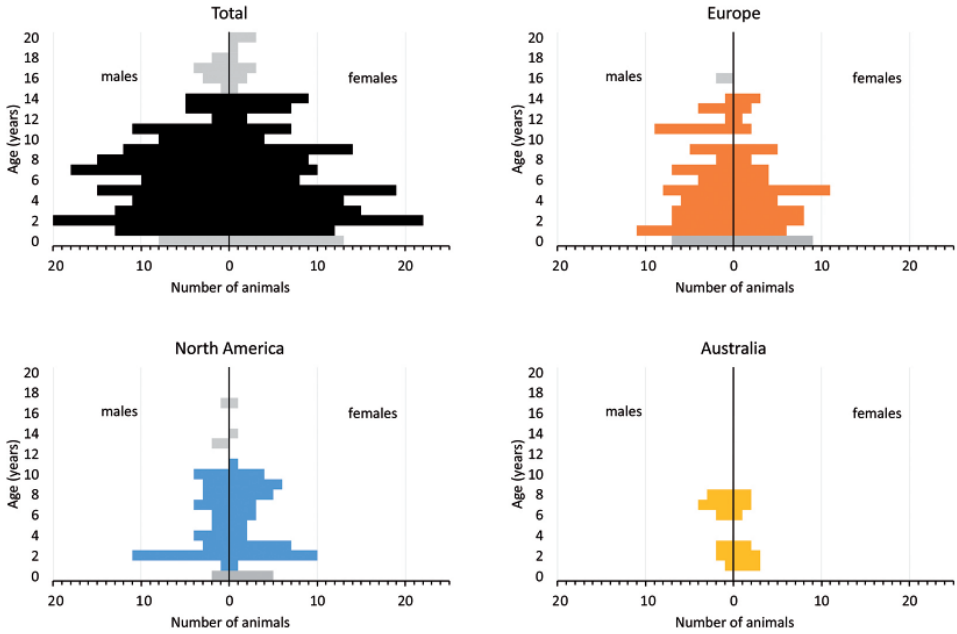

Fig. 2: Age distribution of the total global population of zoo-kept maned wolves including Asia, South America, North America, Europe and Australia, as well as the individual age distribution in North America, Europe and Australia (Holland 2020). Animals over the age of 15 are potentially no longer alive, however, their deaths have not been registered in Species360 Zoological Information Management System (ZIMS) for Studbooks (Holland, 2020).

Free-ranging maned wolves have been classified as generalist omnivores, consuming on average 50% plant material and 50% vertebrates and invertebrates, with some variation between habitats and the wet and dry season (Fig. 3). The plant material most commonly consumed by the maned wolf in its native habitat is *Solanum lycocarpum*, known locally as lobeira or "wolf's fruit" (Dietz, 1984; Lombardi & Junior, 1993; Courtenay, 1994; Motta-Junior & Martins, 2002). *Solanum* species make up the second largest proportion of the biomass consumed by maned wolves, only surpassed by vertebrate prey (Motta-Junior et al., 1996; Bueno et al., 2002; Bueno & Motta-Junior, 2004; de Arruda Bueno & Motta-Junior, 2009).

The formulation of an appropriate diet for maned wolves in zoos is considered to be a major challenge (Songsasen and Rodden 2010), especially because they often appear to respond to minor dietary changes with diarrhoea and poor body condition (Bush 1980). In the 1980s, maned wolves in US zoological institutions were often fed the same raw, meat-based diets normally fed to exotic felids (Rodden et al. 2007). Since then, captive maned wolves in US zoos have been commonly fed diets based on formulations for domestic dogs (*Canis lupus familiaris*) (Songsasen and Rodden 2010).

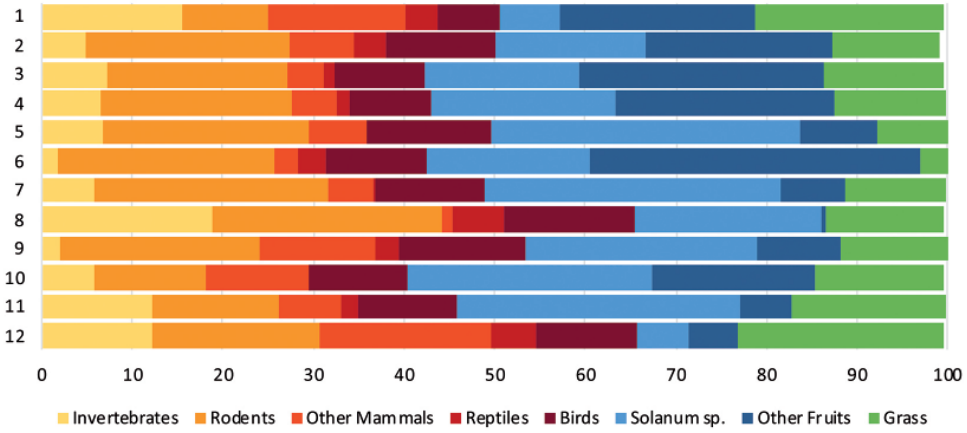

Fig. 3: Proportion of invertebrates, rodents, other mammals, reptiles, birds, *Solanum* sp., other fruits and grass in the diet of free-ranging maned wolves (*Chrysocyon brachyurus*) from various studies. 1 (Aragona & Setz, 2001), 2 (Bueno et al., 2002), 3 (Bueno & Motta-Junior, 2004), 4 (de Arruda Bueno & Motta-Junior, 2009), 5 (Carvalho & Vasconcellos, 1995), 6 (de Almeida Jácomo et al., 2004), 7 (Dietz, 1984), 8 (Massara et al., 2012), 9 (Motta-Junior et al., 1996), 10 (Rodrigues et al., 2007), 11 (Santos et al., 2003), 12 (Silva & Talamoni, 2003).

The most prominently discussed health issue in maned wolves has long been cystinuria, which has been reported in both free-ranging and zoo-kept animals (Bush & Bovee, 1978; Bovee et al., 1981; Mussart & Coppo, 1999). Cystinuria is characterised by elevated levels of cystine in the urine, which can result in the formation of calculi in the kidneys and bladder and thereby cause clinical symptoms (Songsasen & Rodden, 2010). To address the link between meat-based diets and cystinuria, a maned wolf diet that was intended to reduce and prevent cystinuria was formulated in 1998 (Boniface, 1998). The specific maned wolf diet reduced the concentration of cystine in the urine significantly in a sample of four maned wolves and was subsequently modified to include more plant protein instead of animal protein to increase urinary pH (Childs-Sanford, 2005). The feeding of this specific maned wolf diet was discontinued in the US in 2002, after concerns that it could have a negative impact on reproduction, and the feeding of dog food supplemented with fruits, vegetables and small whole prey items recommenced (Songsasen & Rodden, 2010). A survey carried out in 24 US zoos in 2006 found that 15 different brands of dog food were being fed, and there was great variation in the amount and type of fruits, vegetables and whole prey items supplemented. However, no correlations between diet, health and reproductive success could be determined from this survey (Songsasen & Rodden, 2010). Thus, many questions about optimal feeding and health management for maned wolves still remain unanswered.

The reproduction of maned wolves has proven to pose the most significant challenge to the successful maintenance of populations in zoos. In 2010, the target population in North America was 100 maned wolves. Between 2003 and 2007, the population always remained at around 95 animals. However, in 2008 and 2009 reproduction was inexplicably poor and the population dropped to 80 individuals (Songsasen & Rodden, 2010). Historical data from 1982-1998 showed that 53% of pups were lost in the first year and 78% of those deaths occurred in the first 30 days. Of the deaths in the first 30 days, 88% were classified as ‘parental incompetence’, which included pups being devoured, neglected, attacked by the dam or sire, going missing or being stillborn (Maia & Gouveia, 2002). Maned wolves are highly seasonal breeders (Heldstab

et al., 2018) and give birth in the winter season of the respective hemisphere (Fig. 4), which may make the raising of young particularly challenging. In the United States, only 38% of 166 recommended breeding pairs produced pups between 1996 and 2007, 50% of pregnant females losing neonates within a few days after birth (Songsasen & Rodden, 2010). A study by Reiter (2012) indicated a relationship between pup mortality and elevated levels of faecal corticoids, thus suggesting stressors such as poor health and suboptimal enclosures could be causes for neonatal losses. In the Maned Wolf Husbandry Manual from 2007, it is therefore recommended to provide multiple den sites to breeding pairs to reduce stress and install video cameras to closely monitor pregnant females (Rodden et al., 2007). Velloso et al. (1998) found that the reproductive cycle of female maned wolves is reflected in faecal steroid concentrations and therefore suggested testing faecal samples to determine pregnancy in order to prepare more effectively for whelping and potentially reduce the occurrence of infanticide. The true causes of poor reproductive success in maned wolves are unknown and require further investigation.

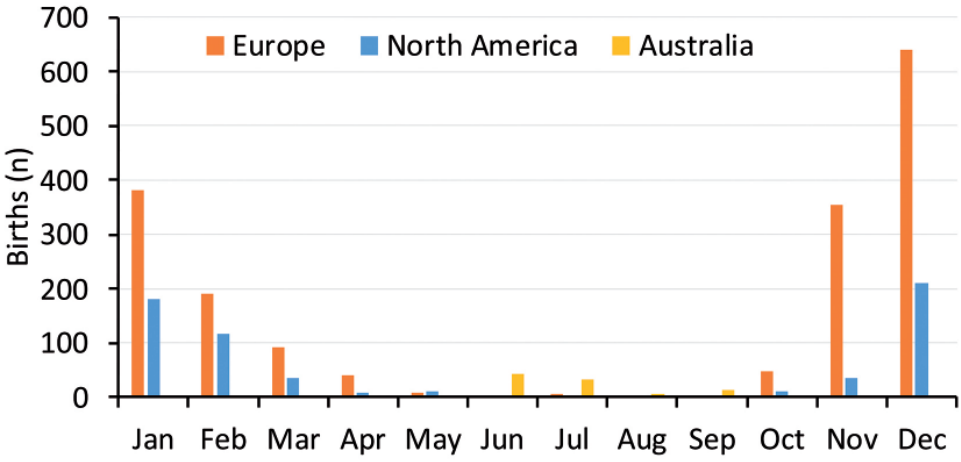

Fig. 4: Birth of zoo-kept maned wolves in Europe, North America and Australia (Holland, 2020).

The aims of this study are to further investigate the causes of poor reproductive success in maned wolves kept in zoos, as well as getting an overview over the main diseases that are currently relevant in the zoo-kept population and the current development of feeding practices. Due to the fact that poor reproduction is a main concern in maned wolf husbandry, data displayed in tables is separated into all institutions and institutions with breeding pairs with and without recent offspring (between 2017-2021).

Materials and methods

This study used a survey to collect information on maned wolf husbandry. The details asked in the questionnaire are evident from the result tables; the original questionnaires can be requested from the corresponding author. Fourty-three facilities with a total of 111 maned wolves in Europe and Australia participated in this study. Previously unpublished data collected from 58 animals in 19 zoos in the United States from 2017 to 2018 was also made available for this study by the nutrition advisor of the Association of Zoos and Aquaria's (AZA) Canid Taxon Advisory Group (TAG). As the zoos did not all provide answers con-

sistently to all questions, the number of facilities for which a specific answer was noted varied between questions.

Of the participating facilities in Europe, only six were visited personally over the course of 2020 due to the travel restrictions during the COVID-19 pandemic. In these facilities, interviews were conducted with curators and/or keepers to gather information on husbandry, feeding, enrichment, medical practices and, where relevant, reproduction. Additionally, any available post-mortem reports were collected for evaluation, the behaviour of the animals was observed, and photos were taken for body condition scoring, to score faeces consistency and to document enclosures. All facilities that could not be visited received a survey containing questions concerning husbandry, feeding, enrichment, medical practices and, where relevant, reproduction. Supplementary data for all zoos was collected by the second author (the studbook coordinator) using the Species360 Zoological Information Management System (ZIMS) for Studbooks.

Descriptive statistics concerning husbandry, feeding, health and reproduction were calculated for the total population surveyed, as well as for institutions with breeding pairs with recent offspring (between 2017-2021) and without recent offspring (between 2017-2021). The statistical analyses used in the software R (R Core Team, 2020) were the chi-squared test and the Wilcoxon signed-rank test functions. No corrections were applied for multiple testing; due to the very large number of statistical tests, these should all be considered exploratory.

Results

Husbandry

The mean number of animals per institution was 2.65, and facilities with breeding pairs with recent offspring had – as expected – significantly more animals than zoos without recent offspring (Table 1). The mean indoor enclosure size per institution was 25 m^2 and the mean outdoor enclosure size 1,459 m^2. Indoor enclosures were defined as a building with one or more boxes inside. The mean indoor enclosure size available per animal was 13 m^2 and the mean outdoor enclosure size available per animal was 557 m^2. Ten of the 62 zoos (16%) did not have indoor enclosures. Instead, these zoos offered only dens in the outdoor enclosure as shelters for the animals. Zoos with no indoor enclosure had a mean number of two outdoor shelters. Zoos with indoor enclosures also had a mean number of two outdoor shelters and additionally had a mean number of 2 indoor shelters.

38 (61%) of the zoos participating in this study had a breeding pair at the time of the survey and 24 (39%) did not. Ten (26%) of the zoos with breeding pairs and seven (29%) of the zoos without breeding pairs reported having more than one outdoor shelter per animal. Of the 32 (84%) zoos with breeding pairs that had an indoor enclosure, eight (25%) reported having more than one indoor shelter per animal. Of the 20 (83%) zoos without breeding pairs that had an indoor enclosure, nine (45%) reported having more than one indoor shelter per animal. The mean temperature in the indoor enclosures or dens (if heated) in winter was 17 °C. Nine zoos (15%) locked their maned wolves in overnight. 19 zoos (31%) locked their maned wolves out during the day in order to increase visibility to visitors, and this was done significantly more frequently among zoos without breeding pairs with recent offspring (Table 1) – possibly, because these zoos had less animals in total.

Data were collected for 84 male and 78 female maned wolves, the groupings of which are further detailed in Figure 5. 24 zoos reported having had same-sex housing either currently or in the past. Of these, 17 (71%) reported male only groups and 9 (38%) reported female only groups. 17 (71%) of these groupings were siblings. All male only groups were reported to have

Tab. 1: Parameters surveyed concerning enclosures and husbandry analysed for all facilities, facilities with breeding pairs with recent offspring (between 2017-2021) and facilities with breeding pairs without recent offspring (between 2017-2021).

	All facilities	Facilities with breeding pairs with recent offspring	Facilities with breeding pairs without recent offspring
	mean ± standard deviation (range; n)		
Number of animals per zoo	2.65 ± 2.43 (0-15; 62)	4.26 ± 3.11[a] (2-15; 23)	2.20 ± 1.37[b] (1-7; 15)
Outdoor enclosure (m^2)	1459 ± 1743 (185-11409; 60)	2194 ± 2528 (230-11409; 23)	1182 ± 918 (185-4000; 15)
Number of zoos with < 930 m^2	27 (45%)	9 (39%)	6 (40%)
Number of zoos with > 930 m^2	33 (55%)	14 (61%)	9 (60%)
Indoor enclosure (m^2)	25 ± 18 (3-100; 44)	31 ± 24 (10-100; 18)	24 ± 13 (9-60; 12)
Mean outdoor size per animal (m^2)	557 ± 402 (77-2300; 60)	553 ± 524 (77-2300; 23)	525 ± 234 (103-1000; 15)
Mean indoor size per animal (m^2)	13 ± 10 (2-50; 44)	11 ± 12 (2-50; 18)	13 ± 9 (5-30; 12)
Indoor enclosure available	52 of 62 (84%)	19 of 23 (83%)	13 of 15 (87%)
Number of outdoor shelters	2 ± 1 (0-6; 60)	2 ± 1 (0-6; 23)	2 ± 1 (0-4; 15)
Outdoor shelters per animal	1 ± 1 (0-3; 60)	1 ± 1 (0-3; 23)	1 ± 1 (0-3; 15)
Number of indoor shelters	2 ± 1 (0-5 ;36)	2 ± 1 (0-4; 14)	2 ± 2 (0-5; 7)
Indoor shelters per animal	1 ± 1 (0-3; 36)	1 ± 1 (0-2; 14)	1 ± 1 (0-3; 7)
Average winter temperature of indoor enclosure or dens (°C)	17 ± 3 (7-24; 38)	18 ± 4 (10-24; 15)	16 ± 4 (7-20; 8)
Locked in over night	9 (of 61; 15%)	3 (of 23; 13%)	1 (of 15; 7%)
Locked out during the day	19 (of 61; 31%)	5 (of 23; 22%)[c]	8 (of 15; 53%)[d]
Time spent indoors in winter (hours per day)	15 ± 5 (0-21; 37)	14 ± 5 (0-21; 15)	14 ± 6 (5-20; 7)
Time spent indoors in summer (hours per day)	8 ± 5 (0-20; 37)	10 ± 5 (1-20; 15)	8 ± 5 (0-14; 7)
Timer spent outdoors in winter (hours per day)	9 ± 5 (3-24; 37)	10 ± 5 (3-24; 15)	10 ± 6 (4-19; 7)
Time spent outdoors in summer (hours per day)	16 ± 5 (4-24; 37)	14 ± 5 (4-23; 15)	16 ± 5 (10-24; 7)

[a-b] Means with different superscript letters differ significantly ($p<0.05$) for successful and unsuccessful breeding pairs for the given parameter (Wilcoxon test).
[c-d] Percentages with different superscript letters differ significantly ($p<0.05$) for successful and unsuccessful breeding pairs for the given parameter (chi-square test).

worked well, whereas two (22%) of the nine female groups were reported to fight, leading to injuries. In one of these groups, the animals were siblings and in the other they were not.

Five zoos had a mixed exhibit at the time of survey, four with giant anteaters and one with tapirs. Two (40%) of the mixed exhibits housed breeding pairs together with giant anteaters. One of the breeding pairs reproduced successfully, the other did not. The other three (60%) mixed exhibits did not house breeding pairs. Two zoos reported having previously successfully housed maned wolves with other species, one with capybaras and one with llamas. These zoos did not have a breeding pair at the time and specified that they believed the mixed exhibit could only be successful as long as neither species had offspring. Two zoos reported having previously had unsuccessful mixed exhibits with capybaras and a male vicuña, which resulted in fighting and hunting of capybara offspring. Both zoos were only housing male maned wolves at the time.

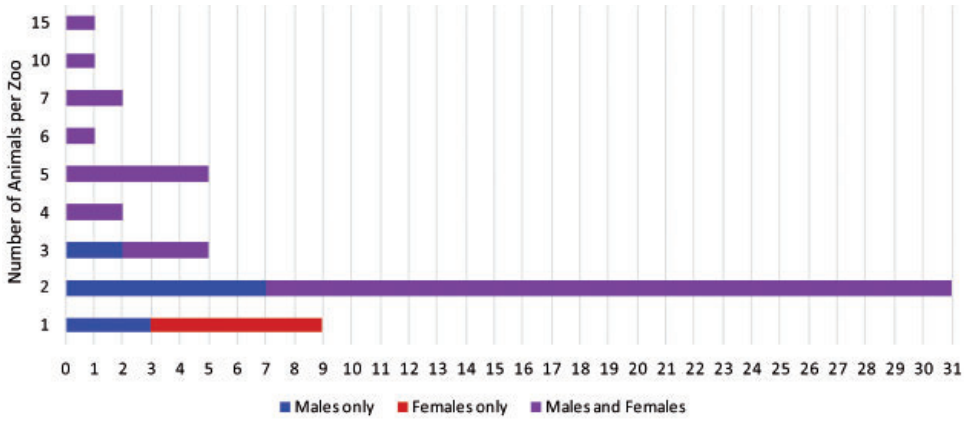

Fig. 5: Number of animals per zoo including differentiation between samesex and differentsex groupings.

The species most commonly housed next to the maned wolf enclosure were herbivores and birds (Fig. 6). 19 zoos (31%) reported that the maned wolves interacted with neighbouring species. Interactions included increased territorial marking in the direction of other canids, increased fighting among hyenas during the breeding season of the maned wolves, maned wolves chasing cheetahs along the fence, maned wolves hunting birds through the fence and species attentively observing each other and vocalising. Seven (30%) of the successful breeding pairs and three (20%) of the unsuccessful breeding pairs had interactions with neighbouring species.

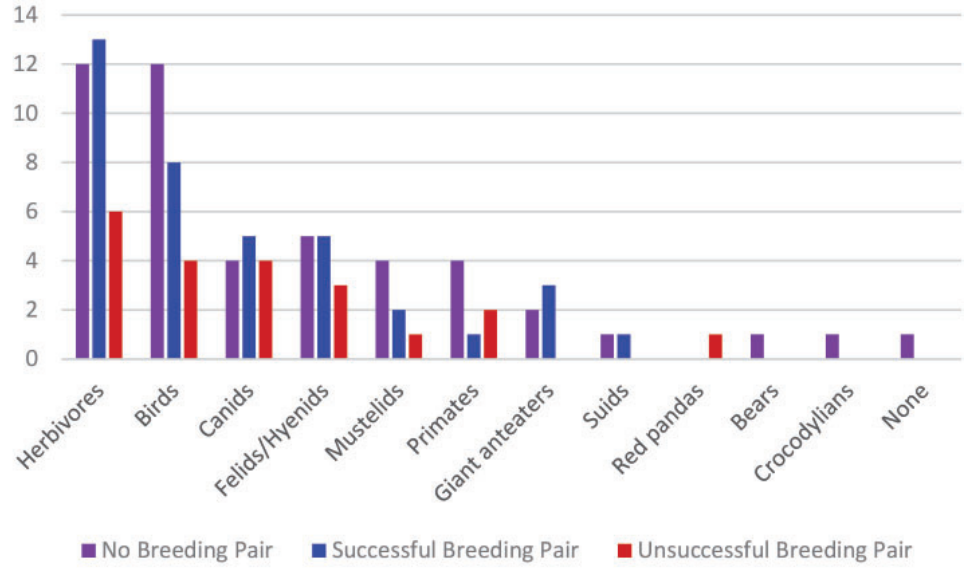

Fig. 6: Species housed next to maned wolves ranked by number of zoos in which they were the closest neighbouring species.

Zoo guests were allowed to bring dogs in 15 zoos (24%), ten of which (67%) reported interactions between dogs and maned wolves. Nine (60%) of the zoos that allowed dogs did not have a breeding pair, five (33%) had successful breeding pairs and one (7%) had an unsuccessful breeding pair. Interactions included maned wolves barking and growling or both parties displaying playful behaviour.

Handling, Behaviour and Enrichment

29 (63%) zoos handled their maned wolves in direct contact and 17 (37%) in protected (indirect) contact (Table 2). 11 (65%) zoos with recent offspring and six (60%) zoos without recent offspring handled their maned wolves in direct contact. 23 (49%) zoos trained at least one command with their maned wolves. Nine (50%) zoos with recent offspring and two (22%) zoos without recent offspring trained their maned wolves. Commands trained included target training, weighing, presenting the mouth, encounters with visitors, applying external ectoparasite treatment in the form of a spot-on, and health checks.

Stereotypic behaviours reported in this study were pacing, which was defined as a maned wolf walking backwards and forwards on an unchanging path for at least five minutes, and fly-catching, which was reported as biting the air without any stimulus or explanation visible to keepers. Stereotypic behaviour was reported by seven (29%) of the total zoos, four (44%) zoos with recent offspring and none (0%) of the zoos without recent offspring.

The most common form of enrichment used across all facilities was having plants in the enclosure, which was used in all (100%) zoos (Table 2). 24 (86%) zoos reported that the maned wolves consumed plants growing in their enclosure, 22 (92%) of which reported the consumption of grass (Table 3). 14 (29%) zoos had water features in the maned wolf enclosure (Table 2), with a number of other zoos citing this as a desired feature. Six (11%) of the total zoos, three (16%) zoos with recent offspring and none (0%) of the zoos without recent offspring, offered piles of sand, dirt or leaves in the enclosure in order to promote hunting behaviour. Four (67%) of the six zoos visited during this study reported that their maned wolves hunted and killed wild animals that entered their enclosure. The most common enrichment methods used during feeding were whole animals (98%), fillable balls (57%), ice blocks (56%), fish (51%) and large bones (50%). The most popular enrichment methods that were unrelated to feeding or the structure of the enclosure were the use of herbs (74%) and bringing in excreta from other species (56%) as an olfactory stimulant. No relevant differences were evident between institutions with breeding pairs with or without recent offspring.

Nutrition and Feeding Management

Two (3%) of the 62 zoos fed an entirely meat-based diet consisting of only whole prey without any fruit or vegetables, while one (2%) zoo fed only Mazuri® Maned Wolf Diet supplemented with whole prey and meat (Table 3). The other 58 zoos (94%) fed an omnivorous diet, all of which (100%) included fruit and 40 (69%) of which included either raw and/or cooked vegetables. The most commonly fed fruit was banana, fed by 46 (82%) of the zoos that gave detailed information on the diet fed to their maned wolves, followed by apples, which were fed by 40 (71%) of these zoos. 38 zoos (61%) reported good acceptance of fruit and vegetables by their maned wolves, 7 (11%) reported poor acceptance and 17 (27%) did not comment on how well fruit and vegetables were accepted. Only one (2%) zoo reported actively feeding grass, wild sunflower and corn stalks as an additional source of fibre.

All but one zoo (98%) fed whole animals and 45 zoos (73%) fed either raw and/or cooked meat. The most common whole prey items were rats, which were fed by 52 (96%) of the zoos that gave

Tab. 2: Parameters surveyed concerning handling, behaviour and enrichment analysed for all facilities, facilities with breeding pairs with recent offspring (between 2017-2021) and facilities with breeding pairs without recent offspring (between 2017-2021).

	All facilities	Facilities with breeding pairs with recent offspring	Facilities with breeding pairs without recent offspring
Direct Handling	29 (of 46; 63%)	11 (of 17; 65%)	6 (of 10; 60%)
Indirect Handling	17 (of 46; 37%)	6 (of 17; 35%)	4 (of 10; 40%)
Training	23 (of 47; 49%)	9 (of 18; 50%)	2 (of 9; 22%)
Stereotypic Behaviour	7 (of 24; 29%)	4 (of 9; 44%)	0 (of 3; 0%)
Enrichment in Enclosure			
Varied Terrain	32 (of 53; 60%)	13 (of 18; 72%)	5 (of 12; 42%)
Plants	55 (of 55; 100%)	19 (of 19; 100%)	13 (of 13; 100%)
Water Features	14 (of 48; 29%)	5 (of 18; 28%)	1 (of 8; 13%)
Objects	49 (of 53; 92%)	17 (of 18; 94%)	11 (of 13; 85%)
Piles of Sand, Dirt, Leaves	6 (of 55; 11%)	3 (of 19; 16%)	0 (of 13; 0%)
Enrichment during Feeding			
Bones	25 (of 50; 50%)	8 (of 17; 47%)	5 (of 11; 45%)
Fish	25 (of 49; 51%)	12 (of 19; 63%)	3 (of 10; 30%)
Rawhide	6 (of 43; 14%)	0 (of 16; 0%)[a]	2 (of 8; 25%)[b]
Crickets	18 (of 46; 39%)	6 (of 18; 33%)	3 (of 8; 38%)
Whole Animals	61 (of 62; 98%)	23 (of 23; 100%)	14 (of 15; 93%)
Coconuts	3 (of 44; 7%)	0 (of 16; 0%)	0 (of 8; 0%)
Ice Blocks	25 (of 45; 56%)	12 (of 17; 71%)	5 (of 9; 56%)
Prey Simulation	6 (of 43; 14%)	4 (of 16; 25%)	0 (of 8; 0%)
Fillable Balls	26 (of 46; 57%)	11 (of 17; 65%)	6 (of 9; 67%)
Olfactory Stimulants and Toys			
Non-Fillable Balls	16 (of 43; 37%)	6 (of 16; 38%)	3 (of 8; 38%)
Filled PVC Pipes	13 (of 43; 30%)	5 (of 16; 31%)	2 (of 8; 25%)
Filled Cardboard Boxes	15 (of 50; 30%)	8 (of 18; 44%)	3 (of 10; 30%)
Sacks	10 (of 50; 20%)	4 (of 18; 22%)	2 (of 10; 20%)
Feathers	19 (of 43; 44%)	7 (of 16; 44%)	2 (of 8; 25%)
Herbs	34 (of 46; 74%)	14 (of 16; 88%)	6 (of 9; 67%)
Excreta from Other Species	24 (of 43; 56%)	11 (of 16; 69%)	4 (of 8; 50%)
Perfume	18 (of 46; 39%)	7 (of 16; 44%)	3 (of 9; 33%)
Commercial Lures	3 (of 43; 7%)	2 (of 16; 13%)	0 (of 8; 0%)
Other Species in Enclosure (for any period of time)	7 (of 49; 14%)	3 (of 18; 17%)	2 (of 10; 20%)

[a-b] Percentages with different superscript letters differ significantly ($p<0.05$) for successful and unsuccessful breeding pairs for the given parameter (chi-square test).

detailed information on the diet fed to their maned wolves. 15 zoos (24%) fed Mazuri® Maned Wolf Diet and 23 zoos (37%) fed a variety of dry dog foods. 3 zoos (5%) fed both Mazuri® Maned Wolf Diet and dry dog food. No zoo (0%) fed exclusively Mazuri® Maned Wolf Diet and only one zoo (2%) fed Mazuri® Maned Wolf Diet as the only source of protein. The only diet items that differed statistically between facilities with breeding pairs with and without recent offspring were less frequent use of dry dog food, eggs and bamboo in those without recent offspring (Table 3).

Anecdotally, keepers observed food caching behaviour by maned wolves, in particular during whelping and pup rearing. Only small prey animals were used for caching but not dry foods, fruits or vegetables.

Health and Veterinary Management

The most commonly reported health concern within the past 15 years was poor body condition, which was reported by 14 zoos (23%) in total (Table 4). None of the reported health issues

Tab. 3: Parameters surveyed concerning nutrition, including how many facilities fed each food group, the voluntary consumption of plants growing in the enclosure and the acceptance of fruit and vegetables offered to the maned wolves.

		All facilities	Facilities with breeding pairs with recent offspring	Facilities with breeding pairs without recent offspring
Raw Meat		44 (of 62; 71%)	16 (of 23; 70%)	9 (of 15; 60%)
Cooked Meat		6 (of 62; 10%)	4 (of 23; 17%)	0 (of 15; 0%)
Whole Animals		61 (of 62; 98%)	23 (of 23; 100%)	14 (of 15; 93%)
	Rats	52 (of 54; 96%)	20 (of 21; 95%)	11 (of 12; 92%)
	Mice	26 (of 54; 48%)	9 (of 21; 43%)	4 (of 12; 33%)
	Rabbits	29 (of 54; 54%)	11 (of 21; 52%)	5 (of 12; 42%)
	Guinea Pigs	21 (of 54; 39%)	8 (of 21; 38%)	4 (of 12; 33%)
	Chicks	27 (of 54; 50%)	10 (of 21; 48%)	4 (of 12; 33%)
	Chickens	22 (of 54; 41%)	6 (of 21; 29%)	5 (of 12; 42%)
	Quails	13 (of 54; 24%)	7 (of 21; 33%)	3 (of 12; 25%)
	Pigeons	6 (of 54; 11%)	3 (of 21; 14%)	0 (of 12; 0%)
	Other	5 (of 54; 9%)	2 (of 21; 10%)	1 (of 12; 8%)
Fish		24 (of 62; 39%)	11 (of 23; 48%)	3 (of 15; 20%)
Dry Dog Food		23 (of 62; 37%)	13 (of 23; 57%)[a]	3 (of 15; 20%)[b]
Mazuri® Maned Wolf Diet		15 (of 62; 24%)	5 (of 23; 22%)	6 (of 15; 40%)
Eggs		26 (of 62; 42%)	14 (of 23; 61%)[a]	3 (of 15; 20%)[b]
Dairy Products		5 (of 62; 8%)	3 (of 23; 13%)	1 (of 15; 7%)
Raw Fruit		58 (of 62; 94%)	22 (of 23; 96%)	13 (of 15; 87%)
	Apples	40 (0f 53; 75%)	17 (of 22; 77%)	9 (of 12; 75%)
	Pears	26 (of 53; 49%)	11 (of 22; 50%)	5 (of 12; 42%)
	Grapes	20 (of 53; 38%)	11 (of 22; 50%)	4 (of 12; 33%)
	Bananas	46 (of 53; 87%)	21 (of 22; 95%)	9 (of 12; 75%)
	Melons	20 (of 53; 38%)	11 (of 22; 50%)	4 (of 12; 33%)
	Tomatoes	13 (of 53; 25%)	4 (of 22; 18%)	2 (of 12; 17%)
	Avocado	10 (of 53; 19%)	3 (of 22; 14%)	3 (of 12; 25%)
	Other	35 (of 53; 66%)	14 (of 22; 64%)	7 (of 12; 58%)
Raw Vegetables		33 (of 62; 53%)	14 (of 23; 61%)	7 (of 15; 47%)
Cooked Vegetables		18 (of 62; 29%)	9 (of 23; 39%)	2 (of 15; 13%)
	Potatoes	12 (of 54; 22%)	4 (of 20; 20%)	2 (of 13; 15%)
	Sweet Potatoes	12 (of 54; 22%)	4 (of 20; 20%)	2 (of 13; 15%)
	Carrots	23 (of 54; 43%)	11 (of 20; 55%)	5 (of 13; 38%)
	Other	18 (of 54; 33%)	7 (of 20; 35%)	4 (of 13; 31%)
Rice		17 (of 62; 27%)	6 (of 23; 26%)	4 (of 15; 27%)
Other (i.e. Honey, Porridge, Dried Fruit)		11 (of 62; 18%)	4 (of 23; 17%)	3 (of 15; 20%)
Supplements		43 (of 62; 69%)	17 (of 23; 74%)	11 (of 15; 73%)
Plants (i.e. Grass, Wild Sunflower)		1 (of 62; 2%)	1 (of 23; 4%)	0 (of 15; 0%)
Plants Consumed in Enclosure		24 (of 28; 86%)	10 (of 11; 91%)	5 (of 7; 71%)
	Grass	22 (of 28; 79%)	9 (of 11; 82%)	5 (of 7; 71%)
	Bamboo	6 (of 28; 21%)	5 (of 11; 45%)[a]	0 (of 7; 0%)[b]
	Other	5 (of 28; 18%)	2 (of 11; 18%)	2 (of 7; 29%)
Acceptance of Fruit and Vegetables				
	Good	38 (of 62; 61%)	14 (of 23; 61%)	8 (of 15; 53%)
	Poor	7 (of 62; 11%)	3 (of 23; 13%)	1 (of 15; 7%)
	Unknown	17 (of 62; 27%)	6 (of 23; 26%)	6 (of 15; 40%)

[a-b] Percentages with different superscript letters differ significantly ($p<0.05$) for successful and unsuccessful breeding pairs for the given parameter (chi-square test).

differed significantly between zoos with successful and unsuccessful breeding pairs (Table 4). Staff at 24 (69%) zoos believed developing an objective body condition score for maned wolves was important. The average weight of all female and male maned wolves (aged 6 months to 15 years) in this study was 25.7 kg and 27.4 kg respectively. The average weight of maned wolves

Tab. 4: Symptoms of possible underlying diseases and diseases that occurred in facilities within the past 15 years, according to responses to the surveys and post-mortem reports. Diseases that only occurred in one or two facilities were not included in the table below. Poor body condition was judged subjectively or by using body condition scoring systems for dogs or cheetahs. No significant differences ($p<0.05$) were found for any of these parameters.

		All facilities (n = 62)	Facilities with breeding pairs with recent offspring (n = 23)	Facilities with breeding pairs without recent offspring (n = 15)
Poor Body Condition		14 (23%)	9 (39%)	5 (33%)
Cystinuria		13 (21%)	4 (17%)	2 (13%)
Nephritis		12 (19%)	5 (22%)	1 (7%)
Dermatitis		11 (18%)	6 (26%)	2 (13%)
Trauma		11 (18%)	5 (22%)	3 (20%)
Inflammatory Bowel Disease		9 (15%)	4 (17%)	2 (13%)
Neoplasia		8 (13%)	5 (22%)	0 (0%)
Cardiopathies		8 (13%)	3 (13%)	1 (7%)
Diarrhoea		6 (10%)	5 (22%)	0 (0%)
Hepatopathies		5 (8%)	2 (9%)	1 (7%)
Gastritis		5 (8%)	1 (4%)	0 (0%)
Enteritis		5 (8%)	0 (0%)	2 (13%)
Conjunctivitis		3 (5%)	2 (9%)	0 (0%)
Ectoparasites		21 (of 43; 49%)	11 (of 16; 69%)	4 (of 8; 50%)
	Ticks	11 (of 43; 26%)	8 (of 16; 50%)	1 (of 8; 13%)
	Fleas	8 (of 43; 19%)	3 (of 16; 19%)	2 (of 8; 25%)
	Ear Mites	5 (of 43; 12%)	2 (of 16; 13%)	2 (of 8; 25%)
	Mites	3 (of 43; 7%)	1 (of 16; 6%)	1 (of 8; 13%)
	Flies	3 (of 43; 7%)	1 (of 16; 6%)	0 (of 8; 0%)

within the optimal age range for breeding (>3 to <8 years of age) was 25 kg for female maned wolves (18.7 kg – 34.2 kg) and 28.5 kg for males (19.2 kg – 37.5 kg). The five most common health concerns for all facilities were poor body condition (23%), cystinuria (21%), nephritis (19%), dermatitis (18%) and trauma (18%). Ectoparasites were reported by 21 (49%) of 43 facilities that gave more specific information on the health of their maned wolves.

39 (95%) of the zoos that gave information on preventative and prophylactic measures reported carrying out faecal exams to monitor parasitic diseases (Table 5). 21 (51%) of these zoos carried out prophylactic deworming and 12 (29%) used ectoparasite prophylaxis. Eight (50%) of the zoos with successful breeding pairs carried out prophylactic deworming and eight (50%) zoos also used ectoparasite prophylaxis. Of the facilities with unsuccessful breeding pairs, six (75%) carried out prophylactic deworming and one (13%) used ectoparasite prophylaxis. 26 (63%) zoos vaccinated their maned wolves against at least one viral disease, meaning 15 (37%) zoos never vaccinated their maned wolves. 12 (75%) of the zoos with successful breeding pairs carried out vaccinations, whereas only three (38%) of the zoos with unsuccessful breeding pairs vaccinated their animals; this difference was significant for the parvovirus vaccination (Table 5).

Reproductive Management

Of the 38 zoos that had a breeding pair at the time of the survey, 23 (61%) were classified as breeding pairs with recent offspring (between 2017-2021) and 15 (39%) were classified as breeding pairs without recent offspring (between 2017-2021). Of the 23 zoos with breeding pairs that produced offspring, four (17%) did not have offspring that survived to the age of one year or older.

Tab. 5: Preventative and prophylactic measures used by facilities in the care of their maned wolves (data from North America were not available for these parameters).

		All facilities (n = 41)	Facilities with breeding pairs with recent offspring (n = 16)	Facilities with breeding pairs without recent offspring (n = 8)
Faecal exams		39 (95%)	15 (94%)	7 (88%)
Testing for Heartworm		6 (15%)	2 (13%)	1 (13%)
Preventative Deworming		21 (51%)	8 (50%)	6 (75%)
Ectoparasite Preventatives		12 (29%)	8 (50%)	1 (13%)
Vaccinations		26 (63%)	14 (88%)	3 (38%)
	Canine Distemper	23 (56%)	12 (75%)	3 (38%)
	Parvovirosis	23 (56%)	13 (81%)[a]	3 (38%)[b]
	Rabies	15 (37%)	6 (38%)	3 (38%)
	Leptospirosis	18 (44%)	8 (50%)	3 (38%)
	Lyme Disease	1 (2%)	1 (6%)	0 (0%)
	Parainfluenza	11 (27%)	5 (31%)	2 (25%)
	CAV-1	17 (41%)	9 (56%)	2 (25%)
	CAV-2	2 (5%)	1 (6%)	0 (0%)
Vaccination Frequency				
	Never	15 (37%)	2 (13%)	5 (63%)
	Annually	14 (34%)	4 (25%)	2 (25%)
	Bi-annually	2 (5%)	2 (13%)	0 (0%)
	Irregularly	7 (17%)	5 (31%)	1 (13%)

[a-b] Percentages with different superscript letters differ significantly ($p<0.05$) for successful and unsuccessful breeding pairs for the given parameter (chi-square test).

43 (69%) zoos gave information on whether or not they had used contraceptive measures in their maned wolves, either at the time of the survey or in the past (Table 6). 13 (30%) zoos had used at least one form of contraception, including six (38%) of the zoos with successful breeding pairs and three (38%) of the zoos with unsuccessful breeding pairs. Five (of 13; 38% or of 43; 12%) zoos used GnRH implants in their male maned wolves, three (60%) of which produced offspring anyway. All other forms of contraception were successful. They were castration, sterilisation, ovariohysterectomy and GnRH implants in females.

Six (10%) zoos did not have a breeding pair at the time of survey, but reported on their latest breeding pair and are therefore included in the following calculations for all zoos, but not in calculations for zoos with or without recent offspring. 24 (86%) breeding pairs were housed together at all times, four (14%) were separated at night and one (4%) zoo with multiple breeding pairs used three different housing constellations, which were breeding pairs always being housed together, only housed together during breeding season and only housed together during oestrus. 13 (87%) successful breeding pairs were housed together at all times and two (13%) were separated at night. All seven (100%) unsuccessful breeding pairs were housed together at all times (Table 6).

Gravidity was most commonly confirmed by observed copulation (73%) and visually observed increase in abdomen size (59%) in all facilities, as well as in facilities with recent offspring (60% and 67% respectively) and facilities without recent offspring (100% and 75% respectively). The dam's diet was changed during gravidity in five (25%) facilities, three (20%) facilities with recent offspring and two (67%) facilities without recent offspring. Changes in keeper routine were also made in five (24%) facilities, three (20%) facilities with recent offspring and one (50%) facility without recent offspring (Table 6). These changes included less movement of keepers in the enclosure, restricted access to the enclosure in the weeks before whelping and reduction of disturbing activities around the enclosure, such as driving by with loud vehicles or carrying out any form of maintenance in the area.

For whelping, four (27%) zoos with recent offspring and none (0%) of the zoos without recent offspring separated the dam and sire (Table 6). A specific whelping pen was available for the

Tab. 6: Parameters surveyed concerning reproduction and reproductive management analysed for all facilities that provided information on past or present breeding pairs, facilities with breeding pairs with recent offspring (between 2017-2021) and facilities with breeding pairs without recent offspring (between 2017-2021).

	All facilities that gave information on past or present breeding pairs	Facilities with breeding pairs with recent offspring	Facilities with breeding pairs without recent offspring
Use of contraception ...	13 (of 43; 30%)	6 (of 16; 38%)	3 (of 8; 38%)
... successfully	10 (of 13; 77%)	3 (of 6; 50%)	3 (of 3; 100%)
Housing of Breeding Pair	**n = 28**	**n = 15**	**n = 7**
Always Together	24 (86%)	13 (87%)	7 (100%)
Separated at Night	4 (14%)	2 (13%)	0 (0%)
Together during Breeding Season Only	1 (4%)	1 (7%)	0 (0%)
Together during Oestrus Only	1 (4%)	1 (7%)	0 (0%)
Gravidity			
Confirmation of Gravidity	**n = 22**	**n = 15**	**n = 4**
Observed Copulation	16 (73%)	9 (60%)	4 (100%)
X-Ray	1 (5%)	1 (7%)	0 (0%)
Visual Increase in Abdomen Size	13 (59%)	10 (67%)	3 (75%)
The Birth Itself	2 (9%)	2 (13%)	0 (0%)
Diet Changes	5 (of 20; 25%)	3 (of 15; 20%)	2 (of 3; 67%)
Behaviour Changes Dam	8 (of 19; 42%)	7 (of 15; 47%)	1 (of 2; 50%)
Changes in Keeper Routine	5 (of 21; 24%)	3 (of 15; 20%)	1 (of 2; 50%)
Whelping			
Separation of Dam and Sire	5 (of 21; 24%)	4 (of 15; 27%)	0 (of 2; 0%)
Fence Contact if No Reintroduction	2 (of 2; 100%)	2 (of 2; 100%)	N/A
Corralled in Familiar Enclosure	2 (of 19; 11%)	2 (of 15; 13%)	0 (of 2; 0%)
Corralled in Unfamiliar Enclosure	2 (of 19; 11%)	2 (of 15; 13%)	0 (of 2; 0%)
Specific Whelping Pen Available	10 (of 20; 50%)	7 (of 15; 47%)	1 (of 2; 50%)
Bedding in Whelping Area	12 (of 13; 92%)	10 (of 11; 91%)	1 (of 1; 100%)
Heat Source in Whelping Area	12 (of 14; 86%)	9 (of 11; 82%)	2 (of 2; 100%)
Light Source in Whelping Area	10 (of 14; 71%)	8 (of 11; 73%)	2 (of 2; 100%)
Temperature Monitoring in Whelping Area	8 (of 14; 57%)	6 (of 11; 55%)	2 (of 2; 100%)
Humidity Monitoring in Whelping Area	1 (of 14; 7%)	0 (of 11; 0%)[a]	1 (of 2; 50%)[b]
Whelping Box or Boxes	10 (of 17; 59%)	7 (of 13; 54%)	2 (of 2; 100%)
Whelping Observed	6 (of 19; 32%)	4 (of 15; 27%)[a]	2 (of 2; 100%)[b]
Lactation Period			
Sire Cleans Pups	5 (of 21; 24%)	4 (of 15; 27%)	1 (of 2; 50%)
Unknown	9 (of 21; 43%)	5 (of 15; 33%)	1 (of 2; 50%)
Sire Regurgitates for Pups	7 (of 21; 33%)	5 (of 15; 33%)	1 (of 2; 50%)
Unknown	11 (of 21; 52%)	7 (of 15; 47%)	1 (of 2; 50%)
Sire Carries Pups	3 (of 21; 14%)	1 (of 15; 7%)[a]	1 (of 2; 50%)[b]
Unknown	10 (of 21; 48%)	7 (of 15; 47%)	1 (of 2; 50%)
Diet Change - Increase	14 (of 19; 74%)	11 (of 14; 79%)	3 (of 3; 100%)
Behaviour Changes Dam	13 (of 18; 72%)	12 (of 14; 86%)	1 (of 2; 50%)
Changes in Keeper Routine	12 (of 20; 60%)	9 (of 14; 64%)	1 (of 2; 50%)
Number of Times Pups are Moved			
Never	7 (of 16; 44%)	4 (of 12; 33%)	1 (of 2; 50%)
Once	2 (of 16; 13%)	2 (of 12; 17%)	0 (of 2; 0%)
At Least Three Times	7 (of 16; 44%)	6 (of 12; 50%)	1 (of 2; 50%)
Access to Larger Enclosure (in weeks post-partum)	2 ± 4 (0-12; 15)	2 ± 4 (0-12; 13)	0 ± 0 (0; 2)
Access to Other Dens (in weeks post-partum)	2 ± 4 (0-12; 15)	2 ± 4 (0-12; 13)	0 ± 0 (0; 2)
Reasons for First Human Contact	**n = 21**	**n = 16**	**n = 2**
Sexing	19 (90%)	16 (100%)	2 (100%)
Weighing	15 (71%)	11 (69%)	2 (100%)
Vaccination	14 (67%)	11 (69%)	1 (50%)
Hand-rearing	1 (5%)	1 (6%)	0 (0%)
Chipping	14 (67%)	12 (75%)	1 (50%)

Tab. 6: Continued.

		Deworming	10 (48%)	7 (44%)	1 (50%)
	Age of First Human Contact (in weeks post-partum)		7 ± 6 (0-24; 16)	6 ± 3 (1-12; 14)	0 ± 0 (0; 1)
	Hand-Rearing Ever Done		5 (of 21; 24%)	4 (of 15; 27%)	0 (of 2; 0%)
	Reason for Hand-rearing		**n = 5**	**n = 4**	N/A
		Restless Behaviour	2 (40%)	1 (25%)	N/A
		Neglect	2 (40%)	1 (25%)	N/A
		Disappearance of a Pup	0 (0%)	0 (0%)	N/A
		Trauma of a Pup	2 (40%)	2 (50%)	N/A
		Death of a Pup	1 (20%)	1 (25%)	N/A
		Zoo Policy	0 (0%)	0 (0%)	N/A
		EEP/Breeding Programme Recommendation	1 (20%)	1 (25%)	N/A
		Other	2 (40%)	2 (50%)	N/A

[a-b] Percentages with different superscript letters differ significantly ($p<0.05$) for successful and unsuccessful breeding pairs for the given parameter (chi-square test).

dam in seven (47%) zoos with recent offspring and one (50%) zoo without recent offspring. Seven (54%) of the zoos with recent offspring and two (100%) of the zoos without recent offspring had whelping boxes for the dam, regardless of if they had a specific whelping pen or not. Whelping was observed directly or via video monitors in four (27%) of the zoos with recent offspring and two (100%) of the zoos without recent offspring.

During the dam's lactation period, 11 (79%) zoos with recent offspring and three (100%) zoos without recent offspring changed the diet fed to the dam by increasing the total amount fed (Table 6). Nine (64%) zoos with recent offspring and one (50%) zoo without recent offspring changed the routine of their keepers during the lactation period in order to cause less disturbances to the dam and her pups. Of the zoos with recent offspring, four (27%) reported the sire participating in cleaning the pups, five (33%) reported the sire participating in regurgitating for the pups and one (7%) reported the sire participating in carrying the pups. Of the zoos without recent offspring, one (50%) reported the sire cleaning, regurgitating for and carrying the pups. In four (33%) zoos with recent offspring and one (50%) zoo without recent offspring, pups were never moved by their parents. In six (50%) zoos with recent offspring and one (50%) zoo without recent offspring, pups were moved at least three times.

The dam or pair was given access to a larger enclosure and additional dens on average two weeks after whelping in all facilities and facilities with recent offspring, and immediately after whelping in facilities without recent offspring (Table 6). The first human contact with the pups was at seven weeks after whelping on average, at six weeks after whelping in facilities with recent offspring and immediately after whelping in facilities without recent offspring. Five (24%) zoos reported having hand reared pups at some point, four (27%) of which were zoos with recent offspring and none (0%) of which were zoos without recent offspring.

Discussion

These results represent a comprehensive comparative analysis of maned wolf husbandry and management practices across European, North American and Australian zoological institutions. Evident limitations of the study apply, including the fact that not all facilities keeping maned wolves were responsive, that not all responsive facilities answered all questions, and that even though answers were most likely given to the best of the respondents' knowledge, these answers need not necessarily match actual conditions that would have been observed had actual visits

been feasible. Nevertheless, the results of this survey yield important information for maned wolf husbandry; in particular, they suggest that the reproductive management of the species is complex and not easily fixed by a few, readily detectable factors.

Factors Affecting Reproduction

This survey did not yield evidence for factors clearly associated with the low reproductive success of the current maned wolf population; therefore, we can only speculate on factors that might be relevant. A significant limitation to the statistical reliability of these results is that pups that are stillborn and/or immediately eaten by a parent or sibling are not always discovered or reported, therefore potentially skewing the findings. The first-year mortality of maned wolves has not improved over recent decades, most recently even increasing despite attempts to improve reproductive success in the species (Roller et al., 2021). In this study, of the 23 zoos with breeding pairs that produced recent offspring (between 2017-2021), four (17%) did not have offspring that survived to the age of one year or older. No significant differences were detected between these four zoos and the 19 zoos with surviving offspring; however, this is potentially due to the small sample size of zoos without surviving offspring and may warrant further research.

Stereotypic behaviours were not observed in unsuccessful breeding pairs, but in 44% of successful breeding pairs. Observations carried out during this study suggested that female maned wolves that were housed with previous offspring close to or during their next fertile period and potential gravidity were most likely to show signs of stereotypic behaviour. Anecdotal evidence from keepers suggested that previous offspring being present when a new litter was born frequently resulted in the litter being eaten by a parent or sibling. Rodden et al. (2007) states that most zoos separate pups from parents when the pups are close to ten months old, to prevent interference with the next breeding season. However, there appears to be some evidence from free-ranging populations suggesting female offspring may be involved in assisting in raising their mother's next litter (Rodden et al., 2007).

Paternal parenting behaviour has been described in maned wolves (Veado, 1997) and a higher rate of survival has been observed in pups raised by both parents, rather than just by the dam. Furthermore, female pups that were raised by both parents are more likely to successfully raise future litters of their own (Bestelmeyer, 2000). Dietz (1984) observed at least one free-ranging male maned wolf involved in the parental care of his pups, assuming that he was bringing food to the dam while she remained in the den with the pups. Anecdotal evidence from multiple keepers interviewed during this study indicated similar behaviours, stating that in the first weeks post-partum, the sire would bring food to the dam while she remained in her den. As soon as the pups were old enough to start eating small prey items, the sire would become more involved in supplying the pups with food and the dam would recommence feeding herself. These observations are also corroborated by Rodden et al. (2007). Therefore, the recommendation of housing pairs together year round was made in the 2007 Maned Wolf Husbandry Manual, which was done by all zoos with unsuccessful breeding pairs in this study and 87% of zoos with successful breeding pairs. Of the zoos with recent offspring, four (27%) reported the sire participating in cleaning the pups, five (33%) reported the sire participating in regurgitating for the pups and one (7%) reported the sire participating in carrying the pups. For each of these three questions, around 50% of zoos stated that they could not be sure whether or not the sire showed parental behaviours; therefore, paternal involvement is potentially much more frequent. All this evidence supports the recommendation to allow the sire to remain with the dam throughout all stages of reproduction and to monitor his paternal behaviours in order to aid future decisions for the breeding pair.

Rodden et al. (2007) states that video monitoring should be possible in nesting boxes offered to female maned wolves. In this study, whelping was observed directly or via video monitors in four (27%) of the zoos with recent offspring. Video monitoring could be a valuable tool for zoos with recently successful or unsuccessful breeding pairs, as video footage would improve observations of how many pups are born and lost in each litter, and of pairs that are potentially breeding but lose the entire litter before pups emerge from the den. In this study, zoos with unsuccessful breeding pairs (53%) locked their maned wolves out during the day significantly more than those with successful breeding pairs (22%). This could be an effect of zoos with unsuccessful breeding pairs having less animals for display. Nevertheless, not locking the maned wolves out from the beginning of the breeding season to the end of the normal whelping season should be attempted and evaluated as a potential mitigation of lost pregnancies or litters.

Brady & Ditton (1979) state that disturbing a dam with her pups will trigger an attempt to relocate her pups, and failure to do so will lead to the neglect or killing of the pups. Rodden et al. (2007) also recommends keeping disturbances directly after whelping to an absolute minimum, stating pups should ideally not be handled until they receive their first vaccinations at six to eight weeks. In our survey, there was a large variability in how many weeks post-partum pups had their first human contact, ranging from directly after whelping, in a zoo concerned about the dam not accepting the pups, to 24 weeks post-partum, in a zoo that did not routinely vaccinate pups. 67% of zoos vaccinated their pups at first human contact. In terms of other disturbances, 60% of zoos made changes to their keeper routine after whelping, including less movement of the keepers in the enclosure and reduction of disturbing or loud activities in the immediate vicinity of the enclosure.

In our study, a significantly higher vaccination rate against parvovirosis was found in zoos with successful breeding pairs (81%) than in those with unsuccessful breeding pairs (38%). Historically, there have been reports of adverse effects of parvovirus vaccination in maned wolf pups (Backues, 1994), as well as vaccination induced canine distemper (Thomas-Baker, 1985). These reports could be a potential reason why some zoos are hesitant to vaccinate their pups; however, vaccinating against these diseases is still recommended using Merial's PUREVAX® Ferret Distemper recombinant canary pox vector vaccine and killed feline parvo vaccines, to minimise the risk of vaccination reactions in pups (Rodden et al., 2007). As Parvovirosis in carnivores has been reported to cause foetal death and embryo resorption, it is especially advisable to vaccinate animals with low reproductive success (Steinel et al., 2001), and our findings support this concept.

Health Concerns Currently Relevant in the Population

In this study, the five most common health concerns occurring over the past 15 years across all facilities were poor body condition (23%), cystinuria (21%), nephritis (19%), dermatitis (18%) and trauma (18%). Observations carried out during this study and anecdotal evidence from keepers and curators suggested that poor body condition was most frequently observed in lactating dams. In the 2007 Maned Wolf Husbandry Manual, the average weight of adult males was 31 kg and that of females was 30 kg (Rodden et al., 2007), whereas in the current study the average weights of adult male and female maned wolves within the optimal breeding range (>3 years to <8 years) were 28.5 kg and 25 kg respectively. As there is, as of yet, no objective body condition scoring system available for maned wolves, it is difficult to discern whether the lower average weights are an indication of a move from optimal to poor body condition, or from animals being overweight to being in optimal condition. As 69% of zoos in this study believed the creation of an objective body condition scoring system to be important and poor body condition appears to be such a prevalent issue in the zoo-kept population, the creation of such an objective tool should be a priority for future management.

The high rates of cystinuria and nephritis reported by zoos in this study are unsurprising, considering the large amount of research already available discussing this issue (Bush & Bovee, 1978; Bovee et al., 1981; Boniface, 1998; Mussart & Coppo, 1999; Childs-Sanford, 2005; Childs-Sanford & Angel, 2006; de Oliveira & das Graças Mendes, 2007). A possible explanation for the high rates of cystinuria and nephritis is that the medical data evaluated within this study spans the past 15 years; however, the most extensive research on improved feeding of maned wolves to prevent cystinuria (Childs-Sanford, 2005; Childs-Sanford & Angel, 2006) was only published around 15 years ago. Therefore, the changes made to feeding practices would not have positively affected animals that were diagnosed with cystinuria and/or nephritis towards the beginning of these 15 years.

The issues of dermatitis and trauma warrant further investigation. Dermatitis could not be statistically linked to the presence of ectoparasites or the use of preventatives against ectoparasites. Therefore, investigations into other causes, such as excessive or stereotypic licking or irritating substances or plants in the environment should be considered.

The 2007 Maned Wolf Husbandry Manual suggests that at least semi-annual faecal exams, treatment against ectoparasites with canine dosages of domestic animal products when necessary, and testing and prophylaxis against heartworm in endemic areas should be part of the medical management of maned wolves (Rodden et al., 2007). In this study, 95% of zoos reported carrying out at least annual faecal exams, 15% of zoos tested for heartworm and 29% used ectoparasite preventative medication, even though 49% of zoos reported their maned wolves having had ectoparasites at least once. Possibly, intensifying ectoparasite surveillance could be advised for maned wolves.

Comparison of Previous and Current Feeding Practices to Natural Diets

According to Rodden et al. (2007), zoos outside North America were feeding small amounts of animal protein in 2007, the bulk of their diets consisting of rice and other grains, fruits and vegetables. The recommendation in the 2007 Maned Wolf Husbandry Manual was that at least 60-70% of the dry matter intake should be made up of nutritionally complete commercial products such as dry dog food, in order to prevent vitamin and mineral deficiencies. However, it was also noted that domestic dog diets containing soybean meal could lead to poorly formed stools and should therefore be avoided (Rodden et al., 2007).

As is illustrated in Figure 7, the proportion of food types fed varied greatly, even within zoos on the same continent. The most notable difference between diets fed in North American zoos in comparison to European and Australian zoos is that North American zoos fed an average of 46% commercial foods (dog foods, Mazuri® Maned Wolf Diet and the category 'Other' in Fig. 7), whereas European zoos fed only 8% commercial foods and the Australian zoo fed 7% commercial foods.

The most distinct differences between all of these diets and the diets of free-ranging maned wolves are the almost complete lack of grasses in the zoo diets, as well as a far lower proportion of invertebrates and the complete lack of *Solanum sp.* (Fig. 1 & Fig. 7). Only one zoo in this study actively fed grasses and other fibrous plants as a source of fibre and enrichment. 86% of zoos reported that their maned wolves consumed plants growing in the enclosure, thereby underlining the importance of making these plants available to the animals, potentially supplementing them with alternatives in winter, and selecting the plants, especially grasses, growing in the maned wolves' enclosure with particular care.

It is also noteworthy that in all 12 studies concerning the diets of free-ranging maned wolves considered in Fig. 1, the proportion of animal matter (including invertebrates) and plant matter consumed is consistently almost equal. As most of these studies used scat samples to make these

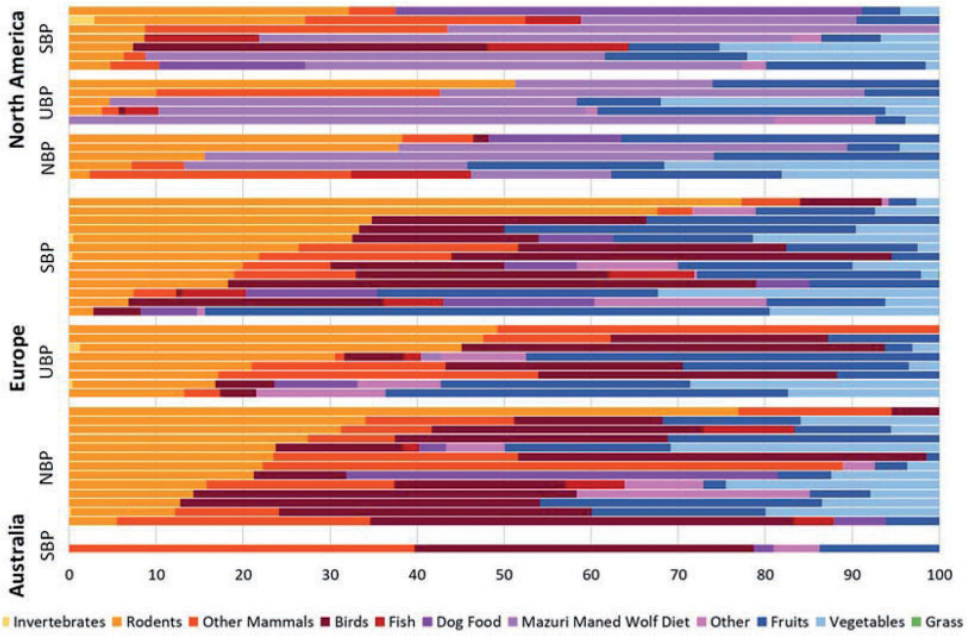

Fig. 7: Proportion of invertebrates, rodents, other mammals, birds, fish, fruits, vegetables, grass, dog food, Mazuri® Maned Wolf Diet and other foods in the diet of maned wolves kept in zoos in North America, Europe and Australia. (SBP = successful breeding pairs, UBP = unsuccessful breeding pairs, NBP = no breeding pairs).

analyses, it is important to note that plant matter and certain parts of invertebrates are less easily digestible than most vertebrates. It is therefore likely that the proportion of vertebrates consumed is somewhat higher than discernible in these studies. Bearing this in mind, there is still a strong contrast between these natural diets and the two (3%) zoos that fed an entirely meat-based diet consisting of only whole prey without supplementation of fruit, vegetables or grains and the one (2%) zoo that fed only Mazuri® Maned Wolf Diet supplemented with whole prey and meat. It is important to note that only 61% of zoos reported good acceptance of fruit and vegetables, 11% reported poor acceptance and 27% did not comment on acceptance. A general consensus of the keepers interviewed during this study was that maned wolves will always eat the meat or whole prey portion of their diet first, then the fruit portion, and vegetables are most often left over. Therefore, the total amount of meat or whole prey fed is essential in deciding whether the animals will still be hungry enough to eat fruits and vegetables afterwards. Bearing this in mind, the formulation of maned wolf diets should not only focus on the proportion of animal protein to fruits and vegetables, but also the total amount of these foods offered. Anecdotal evidence from keepers in some of the zoos visited during this study suggested that maned wolves responded with diarrhoea to the introduction of new fruit and vegetables, as well as the sporadic feeding of fish. The implication of this could be that novel fruits and vegetables should be tested for longer periods of time in order to discover whether the maned wolves' digestive system will grow accustomed to these foods or if there is a true intolerance.

As maned wolves show food caching behaviour similar to red foxes and other carnivores (Macdonald 1976), a diet made up of commercial foods that does not include any small prey items restricts this natural behaviour. Restricting food caching behaviour could have a negative

impact on the reproductive success of maned wolves, as this behaviour was most notably observed and reported during the whelping and pup rearing season in this study. Keepers reported sires bringing food to their dams in the weeks after whelping, which they would then eat or cache for a later time. A lack of food to cache during this critical period could contribute to motivations for infanticide or neglecting of the pups. Furthermore, when pups were old enough to begin eating small prey items themselves, some sires were observed both bringing these to their pups as well as caching them and digging them up for the next day. As the only foods reportedly cached by maned wolves were small prey animals, at least some portion of the diet should be made up of small prey items to allow for this behaviour. Possibly, increasing the amount of small prey during the lactation period could be beneficial for both behavioural and energetic reasons, and should be investigated in practice.

Conclusion

Unfortunately, the results of this study do not allow for any evidence-based recommendations. However, in order to address the poor reproductive success of the species, monitoring of the whelping den during whelping season could be a useful step to gather more information on the current situation as a whole, but also to enable zoos to gain a better understanding of their individual breeding pairs. It is also advisable to offer dams multiple den sites that are warm enough and freshly padded for the whelping season, in order to give options for the safe movement of pups in cold temperatures. Based on the observations made during this study, it is also recommended to remove previous offspring from the breeding pair at the time of the new breeding season and allow the sire to remain with the dam and pups, unless there are individual reasons that indicate this to be a poor choice for a specific breeding pair. In order to mirror natural diets more closely, zoo diets should aim to achieve a more equal balance of plant and animal material, especially focusing on supplying sources of fibre such as grasses and allowing for food caching behaviour by offering small prey animals, in particular during the whelping and lactation period. These dietary changes could yield positive results in the prevalence of cystinuria and nephritis, as well as poor body condition. Therefore, a regular re-evaluation of these medical concerns would be beneficial to verify a possible reduction in prevalence in the population. Additionally, in order to evaluate the issue of poor body condition more objectively, it would be valuable to prioritise creating an objective body condition scoring system for this species.

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Zusammenfassung

Die Mähnenwolf-Population *ex situ* weist historisch einen geringen Fortpflanzungserfolg und eine hohe Prävalenz von Cystinurie auf, was mit einer auf tierischen Bestandteilen basierten Fütterung dieser omnivoren Art zurückgeführt wurde. Eine Umfrage bei 62 europäischen, nordamerikanischen und australischen Zoos zu Haltung, Fütterung, Fortpflanzung und tiermedizinischer Betreuung sammelte Angaben zu 169 Tieren (81 weibliche, 86 männliche und 2 ohne Geschlechtsangabe) im Alter von einem Monat bis 16 Jahren. Diese Studie zeigt auf, dass das

paternale Elternverhalten, restriktiver Zugang zu Innengehegen, die Anwesenheit der Nachkommen des vorigen Jahres sowie lückenhaftes Monitoring wichtige Faktoren für den Fortpflanzungserfolg sein könnten. Die häufigsten für die letzten 15 Jahre genannten Gesundheitsprobleme waren schlechte Körperkondition, Cystinurie und Nierenentzündung. Die Fütterung variierte erheblich zwischen Zoos, wobei nordamerikanische Zoos typischerweise das Mazuri® Maned Wolf Komplettfutter einsetzten oder kommerzielles Hundefutter, während europäische und australische Zoos kleine Beutetiere mit unterschiedlichen Anteilen von Obst und Gemüse fütterten. Der wichtigste Unterschied aller Zoo-Rationen zur natürlichen Nahrung war ein Mangel an Gräsern und *Solanum*-Früchten. Die Ergebnisse legen nahe, dass Zoo-Rationen die natürliche Nahrung eher imitieren würden, wenn sie gleiche Anteile an tierischen und pflanzlichen Bestandteilen enthielten; dies könnte möglicherweise auch zur Behebung von schlechter Körperkondition und Cystinurie beitragen. Um den ausbleibenden Zuchterfolg nachhaltig zu beheben, sind gezielte Studien inklusive eines genauen Monitorings während der Jungtieraufzucht notwendig.

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