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Pygmy slow loris (*Nycticebus pygmaeus*) European zoo diet survey results

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Abstract

The captive population of Pygmy slow loris (*Nycticebus pygmaeus)* in European zoos is managed by a European Endangered Species Programme (EEP). However, there are so far no available nutrient recommendations for this species. With the consent of the Prosimian Taxon Advisory Group (TAG), a nutrition questionnaire was circulated to the 30 EEP participants asking about the ingredients for their *N. pygmaeus* diets, presentation, and related health issues. Only 16 replied (53%), 15 of which included adequate nutritional information. The replies revealed that diets in practice reflect the lack of guidelines and are not based on research evidence that *N. pygmaeus* is an exudativore, feeding on gum, nectar and insects. Therefore none of the reported diets are appropriate or conducive to optimum health and welfare. Nutrition guidelines are essential to improve the husbandry of all lorisid taxa kept in zoos.

Introduction

The pygmy slow loris (*Nycticebus pygmaeus*) is the smallest of the lorisid primates, endemic to Vietnam, Laos, southern China and eastern Cambodia (Starr et al. 2012). They have been observed living in bamboo forests mixed with hardwood trees, forest edges and dense scrubland (Nekaris and Bearder 2011), and are described as vulnerable according to Streicher et al. (2008). The increasing pet trade and demand for Asian medicinal ingredients, coupled with habitat loss has led to a decrease in the total population size (Streicher et al. 2008).

Factual data on behaviour, ecology and nutrition has only come to light recently. Along with other members of the Strepsirrhini, all lorises have long been classified as frugivores, with opportunistic ingestion of vertebrate and invertebrate prey and the occurrence of gum eating (Charles-Dominique 1977; Stevens and Hume 1995; National Research Council 2003). Following more recent and extensive research *N. pygmaeus* is now classified as an exudativore; gum and other exudates, such as nectar, are actually the main components of their diet, with their behaviour specialising in eliciting exudate flow (Tan and Drake 2001; Streicher 2009; Nekaris and Munds 2010; Nekaris and Bearder 2011, Starr et al. 2011; Starr and Nekaris 2013; Streicher et al. 2013). This behaviour, known as gouging, is rare amongst primates and is known to occur in only five other genera: *Cebuella*, *Callithrix*, *Euoticus*, *Mico* and *Phaner* (Coimbra-Filho and Mittermeier 1978; Smith 2010). Pygmy slow lorises were also observed consistently stalking and ingesting insects, specifically slower species that would be found repugnant by other primates due to the production of strong odorous chemicals as a defence mechanism (Fitch-Snyder and Schulze 2001; Nekaris and Bearder 2011).

The European population is managed through a European Endangered Species Programme (EEP) by the European Association of Zoos and Aquaria (EAZA). The EEP, which boasts 30 member institutions, is necessary in a captive setting to maintain adequate genetic variation and concentrate *ex-situ* research needs (Hosey et al. 2009). One focus of the EEP is nutrition; it has been suggested that the goal of a nutrition programme within a zoo should be to cater for the animal's morphological, behavioural and physiological adaptations (Kaumanns et al. 2000). An analysis of the current captive diets offered to *N. pygmaeus* within the EEP has not yet been conducted, therefore it is not known whether or not these three needs are being met.

One modern idea of zoo nutrition is based on the premise that the ideal diet should mimic the wild nutritional ecology of a particular species (Hile 2004). Under this principle, it is believed that the wild-type diet will maximise animal health, longevity and, consequently, reproductive output (Hile 2004). This is difficult when the majority of zoo diets are based on anecdotes and tradition, instead of evidence-based science (Streicher et al. 2013). Health issues are rampant in the captive *N. pygmaeus* population, which supports the theory that not all needs are being adequately met (Fitch-Snyder and Schulze 2001). Health issues possibly related to diet include renal impairments such as chronic interstitial nephritis and cholelithiasis, dental diseases such as facial abscesses, recurring periodontal diseases, facial swelling and osteomyelitis of the zygomatic arch and obesity (Rasmussen 1986; Ratajszczak 1998; Debyser 1995; Fitch-Snyder and Schulze 2001; Fuller et al. 2013). The effects of premature death and low reproductive output can be very important for a small captive population, and indeed this population is not self-sustaining (Debyser 1995; Fitch-Snyder and Schulze 2001; Fuller et al. 2013).

There is a need to identify what is currently being fed to the captive population of *N. pygmaeus* in zoological institutions and evaluate whether or not these diets are appropriate in terms of the evolutionary adaptations of this species. This study aims to investigate the current diets fed to *N. pygmaeus* within the EEP and critique the current feeding standards. An appropriate alternate feeding regime will be recommended if deemed necessary.

Methods

With support from the EEP coordinator and the EAZA Prosimian Taxon Advisory Group (TAG), a survey was sent to all 30 institutions taking part in the EEP. Data collection was scheduled during June to August 2013, to give ample time for the participating zoos to return their survey. The survey was sent in Microsoft Word 2010 format via e-mail, along with the option for the same survey to be completed online by a Survey Monkey link if the institution preferred it. Sample diets were then analysed using Zootrition software version 2.6 and the amount of energy provided by each diet was tested for a significant difference from the recommended amount using a one sample t-test for differences on SPSS version 20 (IBM).

The weights of the lorises were acquired from the Zoological Information Management System (ZIMS). Captive and wild weights were compared and analysed for a significant difference using a one sample t-test for differences on SPSS version 20 (IBM).

Results

Survey data

A total of 16 zoos (53% of EEP members) responded to the survey (11 Word documents, five Survey Monkeys), of which 15 provided adequate data on their animals' current diets. The surveys covered a total of 26.17.3 adults, including 12 breeding pairs (52% of the surveyed adult population), 1.3.1 juveniles and 0.0.5 new-borns. Of these, 23 individuals were held in nocturnal enclosures and 33 in diurnal enclosures. In terms of a weekly rota (details in Table 1), every zoo reported feeding fruit, 14 reported feeding vegetables, 13 invertebrates, 10 a vertebrate prey item, eight a concentrate pelleted feed, seven an exudate such as gum or jelly, six grains, four dairy, and one nectar. Supplements were only given by five zoos: as reported, these were Vitamin D3 liquid supplement (three zoos), complete multivitamin (one), whey protein (one), honey (one), teeth stone powder (one), SA50 Vitamin Powder (one), Cytacon liquid (one), and Abidec (one).

Food was mostly presented once a day (10 zoos), with schedules of two and three times a day being reported by three zoos each. Food was generally presented in a some sort of container (metal bowls, empty coconuts etc). These were attached to branches by 12 zoos, with the remaining three zoos placing their bowls on a flat surface or platform. Enrichment was given at least once a week by 11 zoos; details of food enrichment are given in Table 2. All diets except for two had been in use for at least two years, but the more recent diets were still included in this study.

The health issues disclosed by the surveys include digestion issues (one zoo), facial abscesses (one zoo), dental problems (10 zoos), obesity (two zoos) and pelage/fur problems (one zoo).

Diet analysis

Nine diets were chosen because of the adequacy of their data presentation and their nutrient contents analysed using Zootrition. The macronutrients and micronutrients chosen for investigation were the ones believed most important and best represented by the software's available data. These results can be seen in Table 3.

The amounts of energy provided for each diet as reported in Table 3 were tested with a one sample t-test against the average of 41 Kcal (value provided from the field metabolic rate (FMR) equation of Hayssen and Lacy (1985) using 420 g as the average wild weight). The energy provided by nine sample diets was significantly different than the average needed to attain the target weight of 420g ($t_{[8]}$=5.19, p=0.001) with a mean difference of 36.87.

Weight scores

Using ZIMS, it was possible to find 26 male and 17 female weights that corresponded perfectly to the adult survey population. Male weights ranged from 350g to 707g with an average of 506g (+/- 18.4). Female weights ranged from 306g to 800g with an average

Table 1. Items fed to pygmy slow loris (*Nycticebus pygmaeus*) within European zoos. Numbers in brackets are number of zoos feeding that item out of 15 zoos in total.

Fruits (15)	apple (11), banana (9), grapes (9), pear (8), melon (5), citrus (4), papaya (3), raisins (3), peach (3), pineapple (2), tomato (2), mango (2), plum (1), avocado (1), kiwi (1), blueberry (1), strawberry (1), dried fruits (1), date(1)
Vegetables (14)	carrot (9), cucumber (7), peppers (3), broccoli (3), potato (3), lettuce (3), celery (2), swede (2), butternut squash (2), courgette (2), parsnip (2), beetroot (1), sweet potato (1), cauliflower (1), endive (1)
Invertebrates (13)	orthopterans (10), mealworm (7), zophobas (4)
Vertebrate items (10)	hard boiled egg (9), boiled chicken (4), chick (2), boiled beef (2), pinky mice (1), minced meat (1)
Pellet feeds (8)	Mazuri Trio Munch (3), Mazuri Leaf Eater (1), Mazuri Mini-Marex (1), Mazuri Marmoset Pellets, Mazuri Tamarin Cake (1), Kasper G.O. (1), Hassell Marmoset Pellets (1), Mazuri Zoo Diet A (1)
Exudates (7)	gum arabic (5), marmoset jelly (2), Mazuri marmoset gum (1)
Grains (6)	cooked rice (4), cereal mush (3), flax seeds/meal (2), shoots of wheat (1), wholemeal pulp (1)
Dairy (4)	yogurt (4), cottage cheese (1), cheese (1)
Nectar (1)	

Table 2. Types of food enrichment provided by zoos for *N. pygmaeus.* Numbers in brackets are number of zoos feeding that item out of 15 zoos in total.

Insects	mealworms, crickets and locusts (9)
Browse	bamboo (2), willow (2), oak (1), ficus, (1),birch (1), palm tree (1)
Food presentation	food smearing (3), placing food in boxes/rolls, moveable hanging baskets (1), hanging food on string (1)

of 530.g (+/-32.0). Both the male ($t_{[24]}$=4.76, p=0.000) and female ($t_{[16]}$=3.388, p=0.004) weights were significantly greater than the average wild weight of 420g.

Discussion

The large variation in diet ingredients and amounts fed by different zoos highlights the absence of a feeding standard for this species across Europe. The ecological role that *N. pygmaeus* is traditionally believed to have stems from a study on the potto (*Perodicticus* spp.), which is an entirely frugivorous lorisid (Charles-Dominique 1977). It was assumed that all lorisids have a similar niche and only varied in size. Only Streicher et al. (2013) specifically reported *N. pygmaeus* as seasonally eating some fruit but never subsisting on it. This study followed reintroduced individuals to determine their dietary preference and determined that gum and plant exudates were the essential food items for lorises. During their captivity, the wild-born specimens rejected most fruits, boiled eggs and vegetables (Streicher et al. 2013). Nekaris and Bearder (2011) reported the wild diet composition to be 33% insects, 63% exudates and 4% other items; Streicher (2009) found it to be 30% exudates, 30% gum and 40% insects and Starr and Nekaris (2013) reported approximately 51% gum, 30% arthropods, 5% fungi, 6% bamboo, and 1% gecko during winter. Seasonality did cause a change of diet in the study of Starr and Nekaris (2013), arthropod consumption decreasing to 10% and plant parts (fruit, flowers and bamboo parts) increasing to approximately 52%.

There is consistency within the wild diet studies, and no evidence to support feeding captive *N. pygmaeus* meat, grains or dairy products. Zoos should instead aim to feed insects daily as a source of protein, lipids and digestive material (Fleagle 2013). Their physiological adaptations are tailored to the specific nutrients found in arthropods due to the presence of chitinase and cellobiase activity in their gastric mucosa (Vonk and Western 1984). Although it still isn't clear how they utilise the chitin, the presence of chitinase and cellobiase would infer they can harness at least some energy from it. Their mixture of quadrupedal and bipedal habits enables them to stalk and catch insects, even quick ones such as orthopterans, lunging with both anterior limbs forward (Streicher et al. 2013). Behaviourally, they are adapted to stalking and catching moving insects, so a variety of insects on a weekly rota could be a good option, instead of only feeding mealworms in a bowl.

The survey found that all zoos currently feed their *N. pygmaeus* fruit. While they have been observed feeding on fruits occasionally, zoos must look at the nutritional quality of wild fruits versus domesticated fruits. Schwitzer et al. (2009) showed that wild fruits are higher in fibre fractions, lignin and protein and lower in non-fibre carbohydrates, such as sugars, and metabolisable energy. Wild fruits are actually reported to resemble our domestic vegetables more than cultivated fruits (Schwitzer et al. 2009). It is highly recommended that zoos phase out fruits from their *N. pygmaeus* diets and replace them with vegetables if the energetic value of an insect- and gum-based diet falls too low.

Considering exudates such as gum and nectar are what *N. pygmaeus* are adapted to sustain themselves on, zoos should try to incorporate these into their diets as much as possible. In this survey a very small number of zoos fed gum, and most institutions only gave it sporadically as enrichment. Gum is usually bought in crystal or powdered form and mixed with warm water, setting into a gum as it cools. This gum, from the acacia tree, provides similar structural carbohydrates and energy to wild gum. Because of the purifying process it has gone through it has lost many of its secondary metabolites, vitamins and minerals. A remedy would be to add a vitamin/mineral supplement to the gum while it is cooling to provide a stable and palatable vector for the micronutrients. Insects are a high source of phosphorous and natural gum is high in calcium, which results in a favourable calcium to phosphorous ratio in the wild (Charles-Dominique 1977). Pelleted feeds are an excellent source of these micronutrients and for any zoos that find it impossible to provide insects and enriched gum in the required amounts, this could be the key to providing adequate nutrients. Only half of the institutions surveyed fed their *N. pygmaeus* pelleted diets. Although they are all similar in composition, some,

Table 3. Nutritional analysis of nine surveyed diets (using Zootrition v2.6), with diet 10 being a naturalistic and fruit-free diet from Cabana and Plowman (2013). Weekly energy and dry mass (DM) amounts were divided by seven to represent an average daily value.

		Diet									
Nutrients	Unit	1	2	3	4	2	6	7	8	9	10
Energy/day	Mj	0.273	0.321	0.274	0.212	0.345	0.421	0.509	0.293	0.287	0.189
Crude Fat	%	11.41	16.38	8.47	21.47	6.97	13.17	11.46	6.23	7.24	9.24
Crude Protein	%	23.59	22.09	23.11	39.14	13.22	19.14	17.53	13.82	24.27	23.77
Iron (Fe)	mg/kg	11.6	27.87	79.38	56.19	90.95	53.52	26.77	16.5*	24.1	36.35
Calcium(Ca)	%	0.8	0.41	1.05	0.46	0.38	0.46	0.25	0.1*	0.83	1.25
Phosporous (P)	%	0.58	0.26	0.79	0.56	0.32	0.47	0.36	0.21*	0.79	0.42
Ca:P Ratio		1.38	1.58	1.33	0.82	1.19	0.98	0.69	-	1.05	2.97
DM	g	18.57	19.41	15.62	10.88	23.15	26.1	29.89	18.81	18.44	13.04

*Data unreliable as nutrient information was available for fewer than 80% of the ingredients in the Zootrition v2.6 database.

such as TrioMunch (Mazuri), do not contain any animal protein, which in naturalistic terms would be preferable due to the low level of vertebrate prey in the diet of wild *N. pygmaeus*. Nutrients can also be provided by offering supplemented nectar as part of their diet. Lorikeet or sunbird nectar available for zoos is usually enriched with macro- and micronutrients, which could act as a supplement for captive *N. pygmaeus*.

Diets should be analysed through nutrition management software such as Zootrition to provide an optimum amount of feed. The nine sample diets' energetic contents were significantly higher than the amount of energy needed for a healthy individual in a captive setting (assuming the target is average wild weight). The average diet provides 0.33 Mj/day whereas the animals only require 0.17Mj/day according to Hayssen and Lacy (1985). Note that this equation has been derived for primates and not specifically for *Nycticebus* spp. The over-provision of food also allows individuals the opportunity to pick and choose what they eat, possibly creating a very biased and skewed nutrient ingestion. Controlling overall energy of diets can help to lower the weight of overweight animals.

Wild weights average 418 g for males (range 367–578 g) and 422 g for females (range 360–543 g) (Nekaris and Bearder 2011). Captive individuals are on average 87.68 g heavier for males and 108.41 g heavier for females and both have been shown to be significantly heavier than in the wild. There is a clear need for zoos to review their diets, including the actual ingredients, quantity and presentation. It has been shown by Cabana and Plowman (2014) that changing a typical zoo diet into a naturalistic diet composed mainly of insects, gum, nectar and vegetables with the same amount of energy, has the potential to increase the occurrence of feeding and travelling behaviours, help decrease abnormal behaviour patterns, and stimulate overweight individuals to lose weight.

Health issues have been reported in many studies and 10 institutions (62.5%) reported dental issues in *N. pygmaeus*. Individuals that are fed diets high in sugar (from fruits) and with little or no gum, as opposed to a fruit free and exudate rich diet, may be at risk of developing dental diseases and obesity (Streicher et al. 2013). Captive, wild and reintroduced *N. pygmaeus* are known to gouge tree branches (Streicher et al. 2013). They use their lower teeth, specialised into a toothcomb, to bite holes into tree branches or trunks to elicit gum or sap flow. The mechanical action of the teeth biting through the cellulose and lignin may be analogous to flossing, and can help to promote dental health (Streicher et al. 2013). Six of the zoos surveyed presented gum in little holes drilled in wooden branches to mimic their feeding behaviour. By providing gum and reducing food items not fed on in the wild such as fruits, grains, dairy and meat, they may benefit from a healthier, longer life with less need for veterinary interventions.

Food presentation is becoming more important in zoo husbandry (see review in Hosey et al. 2009). Three institutions in this study placed the food bowl on a flat surface while the other 12 hung them up on branches. These arboreal primates are used to obtaining most, if not all, of their food on trees. Attaching the feeding bowl to different branches every day would also create an element of unpredictability and may act as enrichment in terms of oraging behaviour (Hosey et al. 2009).

Only two institutions mentioned changing the diet to contain less energy during the winter months. It has been shown by Streicher (2005) that weight fluctuations do occur in both males and females in nature. They begin to gain weight during autumn then lose the weight after December. They can gain and lose up to 200 g for males and 175 g for females (Streicher, 2005). A diet reduced in calories during winter may be beneficial for physiological processes of captive *N. pygmaeus*. However, there is no evidence to support this yet.

Conclusion

By conducting a nutrition survey of the pygmy slow loris (*Nycticebus pygmaeus*) EEP population, it was possible to determine that their morphological, physiological and behavioural needs are generally not being met. Institutions should aim to remove fruits, vertebrate prey, dairy and grain products from their diets and instead phase in more gum, nectar and insects. This has been shown to positively affect the animals' behaviour and is promising in reducing obesity and many of the varied health problems the captive population is afflicted with. More studies need to be conducted to measure the impact that naturalistic diet changes have on long term health and reproductive output.

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