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Morphometrics and Growth in Captive Aye-Ayes *(Daubentonia madagascariensis)*

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Introduction

Prior to 1987, there were few aye-ayes *(Daubentonia madagascariensis)* in captivity and no reported successful breeding. Even though a few had been kept in captivity as early as the 19th century, little was known about them other than a detailed anatomical study by Sir Richard Owen [1] and a 35-page review published by Petter et al. [2]. An investigation into their field biology has only recently begun [3].

Aye-ayes were recognized by Gray [4] as being in their own taxonomic family, the Daubentoniidae. They are found only on the island of Madagascar with one living species, *D. madagascariensis*. Aye-ayes are among the most endangered primates because their habitat is being rapidly destroyed and because they are considered to be bearers of bad luck and death, as a result of which they may be killed. The aye-aye is the only primate that is considered endangered at the specific, generic and family level.

In 1987 Duke University Primate Center (DUPC) brought 2 male aye-ayes into captivity. This was followed in 1988 with the importation of 1 adult female and her 2-month-old female infant. An additional 3 adult females and 1 adult male were imported in December 1991. All of these animals were brought in under an Accord of Agreement with the Government of Madagascar. As of January 1994, there are 26 individuals in captivity [5 males and 5 females at Duke; 2/6 at the Jersey Wildlife Preservation Trust (JWPT), Channel Islands; 1/1 at Vincennes, Paris; 1/1 at Parc Ivoloina, Madagascar, and 2/2 at Parc Tsimbazaza, Madagascar). This captive population includes 5 surviving individuals (2/3) that were born in captivity.

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In this paper, I provide information on birth weight, gestation length and rate of growth for captive aye-ayes at the DUPC.

History of the DUPC Aye-Aye Colony

The first 2 aye-ayes (both male) arrived at the DUPC in December 1987. Nosferatu was mature and estimated to be 8 years old on arrival, while Poe was estimated to be about 2 years old. (Estimated age is based on overall tooth wear. In blind tests, my estimated ages based on tooth wear for other lemurs have been within ± 2 years of the known ages.) In August 1988, an adult female (Samantha) and her female infant (Anabel Lee) joined the 2 males. Samantha was estimated to be 15 years old and Anabel Lee to be 2 months old on arrival. The infant died in August 1989 at an estimated age of 440 days, of undetermined causes. In December 1991, 3 females and 1 male joined our 3 resident aye-ayes. One of the females (Morticia) was nulliparous and estimated to be 3 years old on arrival. The other 2 females were estimated to be 8 (Endora) and 6 years old (Ozma) on arrival. The male (Mephistopheles) was estimated to be 10 years old.

Four infants have been born in the colony since 1992 and 3 still survive. The first birth of an aye-aye infant in captivity occurred at the DUPC on April 5, 1992, when Endora gave birth to an infant male named Blue Devil. He was conceived in the wild. The first birth of an aye-aye infant conceived at the DUPC occurred on October 23, 1992. This male infant is named Goblin. His mother is Ozma, and Mephistopheles is his father. On December 13, 1992, a female infant was born to Samantha. Nosferatu was the father. This infant died on December 14, 1992. A female infant (Cruella) was born to Morticia on October 8, 1993. Her father is Poe.

Table 1. Description of measurements

Arm length	from the axillary region to the tip of the longest digit, excluding the nail
Leg length	from the groin to the end of the longest digit, excluding the nail
Third digit	from the junction with the palm to the end, excluding the nail
Tail-crown length	from the tip of the tail to the most anterior point on the head with the head in normal position, i.e. chin near the chest (adding the body and tail measurements together produces tail-crown length)
Tail length	on the ventral side of the tail from the tip of the tail to the junction of the base of the tail with the perianal area; the tail is extended straight out behind the animal
Body length	tail-crown length – tail length
IMI	arm length/leg length × 100

Diet and Housing

Aye-ayes are housed as male-female pairs in indoor rooms measuring 5 m long × 5 m wide × 6 m high [5]. Males are removed 2 weeks prior to parturition and kept out until the infant is more than 6 months old. Two wooden nest boxes and fresh bamboo or juniper branches are provided for nesting. Diet consists of a variety of fruits, vegetables, coconuts, sugar cane, soft cooked eggs, mealworms and waxworms. Logs from the forest surrounding the Primate Center are provided for stimulation.

Methodology

Weights were taken by placing individuals in a holding cage on a tared scale. A metal metric tape was used for the linear measurement of manually restrained individuals. The measurements and intermembral index (IMI) are described in table 1.

Table 2. Morphometrics for Blue Devil (born April 5, 1992)

Date	Age days	Weight g	Arm mm	Leg mm	Third digit mm	Body mm	Tail mm	IMI
6-Apr-92	1	136						
11-Apr-92	6	145						
21-Apr-92	16	275	120	133	32	60	185	90
28-Apr-92	23	350	125	145	35	80	195	86
5-May-92	30	411	135	155	37	90	225	87
12-May-92	37	470	140	155	39	140	240	90
19-May-92	44	510	150	170	39	190	255	88
26-May-92	51	550	160	190	41	215	275	84
9-Jun-92	65	620	165	215	53	240	295	77
23-Jun-92	79	680	170	220	55	240	295	77
7-Jul-92	93	730	170	220	55	240	310	77
21-Jul-92	107	770	190	220	60	240	320	86
19-Aug-92	136	900	200	220	60	240	360	91
22-Sep-92	169	1,050	230	260	65	270	360	88
27-Oct-92	204	1,210	269	295	68	277	408	91
4-Nov-92	212	1,270						
1-Dec-92	238	1,330	285	304	75	330	410	94
30-Dec-92	267	1,430						
31-Jan-93	297	1,520						
4-Mar-93	329	1,640						
25-Mar-93	350	1,720						
22-Apr-93	378	1,770						
21-May-93	408	1,840						
22-Jun-93	439	1,820						
29-Jul-93	476	2,000						
23-Sep-93	532	2,110						
26-Oct-93	565	2,040						
16-Nov-93	586	2,010						
14-Dec-93	614	2,070						
14-Jan-94	644	2,180						
14-Feb-94	674	2,100						
14-Mar-94	702	1,980						

Gestation Length and Morphometrics

The average gestation for the DUPC aye-ayes is 167 days (n = 3) with a range of 158–172 days. Birth weight for Blue Devil was 136 g, for Goblin 108 g, for Samantha's female infant 90 g and for Cruella 102 g (all are day-of-birth weights except Blue Devil's which is from day 2). At approximately 1 year of age, Blue Devil weighed 1,750 g and Goblin 1,320 g. Cruella has not yet reached the age of 1 year. The growth curves for the 3 individuals are similar, except for Goblin shortly after 1 year of age. His mother stopped producing milk (absent in manual expressions) just after he turned 1 year old, and his weight

Table 3. Morphometrics for Goblin (born October 23, 1992)

Date	Age days	Weight g	Arm mm	Leg mm	Third digit mm	Body mm	Tail mm	IMI
23-Oct-92	0	108						
28-Oct-92	1	116	92	100	28	140	150	92
3-Nov-92	5	166	92	112	28	145	170	82
10-Nov-92	11	228	114	125	34	180	171	91
17-Nov-92	18	274	122	127	34	180	188	96
24-Nov-92	25	264	125	130	34	185	200	96
1-Dec-92	32	270	134	140	37	185	205	96
9-Dec-92	39	277	140	152	39	185	216	92
16-Dec-92	47	308	142	155	40	185	235	92
30-Dec-92	54	374	142	160	40	220	235	89
6-Jan-93	68	406	156	160	43	230	235	98
13-Jan-93	75	430	160	180	48	230	245	89
27-Jan-93	83	496	168	200	49	240	250	84
11-Feb-93	97	560	175	200	50	250	280	88
11-Mar-93	111	690	197	225	55	255	320	88
31-Mar-93	139	780	202	230	57	270	335	88
13-May-93	159	910					345	
15-Jul-93	265	1,100	210	250	75	330	360	84
16-Sep-93	327	1,110						
20-Sep-93	318	1,100						
30-Sep-93	341	1,110						
6-Oct-93	348	1,150						
13-Oct-93	355	1,220						
20-Oct-93	362	1,260						
27-Oct-93	369	1,320						
3-Nov-93	376	1,370						
10-Nov-93	383	1,350						
17-Nov-93	390	1,340						
24-Nov-93	397	1,320						
1-Dec-93	406	1,330						
8-Dec-93	413	1,310						
15-Dec-93	420	1,250						
22-Dec-93	427	1,270						
29-Dec-93	434	1,230						
5-Jan-94	441	1,210						
1-Mar-94	536	1,230						

leveled off at a high of 1,370 g and then began to drop to a low of 1,210 g. He was given extra vitamin-enriched food. Blue Devil also leveled off just above 2,000 g and has dropped back below 2,000 g. Tables 2–4 contain the morphometrics for the DUPC infants. The infant males' testicles descended into their scrota between 55 and 65 days of age.

Adult weights ranged from 1,790 g for the smallest, Samantha, to 3,073 g for Nosferatu

Table 4. Morphometrics for Cruella (born October 8, 1993)

Date	Age days	Weight g	Arm mm	Leg mm	Third digit mm	Body mm	Tail mm	IMI
8-Oct-93	0	102						
20-Oct-93	12	145						
26-Oct-93	18	170	102	111	30	160	150	92
2-Nov-93	25	200						
22-Nov-93	45	311	135	140	42	170	200	96
3-Dec-93	57	376						
17-Dec-93	70	430	150	155	50	200	225	97
22-Dec-93	75	450						
7-Jan-94	91	510	200	220	53	210	270	91
21-Jan-94	105	540						
4-Feb-94	119	630	210	300	60	240	300	91
21-Feb-94	136	750						
8-Mar-94	151	830						

(table 5). Males are larger than females. The birth weight of an infant was directly related to the body weight of the mother, i.e. the smallest female had the smallest infant (table 6).

Discussion

The average gestation length of 167 days for aye-ayes is longer than that for other prosimians of similar body size of about 2.5 kg. *Lemur catta* and *Eulemur macaco,* with a body weight of about 2.5 kg, have gestation lengths of 135 and 128 days, respectively [6; DUPC unpubl. records]. JWPT reports a gestation of 158 days for their first aye-aye infant [7]. If this is averaged with the 3 DUPC gestations, the new average gestation length is 164 days (n = 4).

The average body weight at birth of 109 g (n = 4) is considerably less than the extrapolated birth weight of 140 g for the JWPT infant, whose first recorded weight of 255 g was made at 11 days of age [7]. DUPC infants weighed 265, 166 and 145 g at 11 days of age (tables 2–4). The extrapolated birth weight for the JWPT infant could be reasonably accurate, since one of the DUPC infants was similar in actual birth weight and weight at 11 days of age. It is clear that not all infant aye-ayes will be that large, either at birth or at any particular age, since the other DUPC infants varied widely in birth weight and body weight at comparable ages (tables 2–4).

The DUPC infants' birth weights, ranging from 90 to 136 g, were clearly related to their mother's body weight (table 6). The largest adult female (Endora) had the largest infant, and the smallest mother (Samantha) had the smallest infant. In calculating the average body weight for females, the 2 months before birth were excluded for each female. There appears to be no relation between gestation length and infant body weight (table 6). The smallest infant was born to the female with the longest gestation. Infant body weight at birth is variable, but appears to be related to the mother's body size and not gestation length.

Increase in body weight averaged 4 g per day for the 2 DUPC infants that survived to 1 year, with an average body weight of 1,515 g at 1 year of age (tables 2 and 3). Linear measurements were not collected for a complete year, but increase in length is typified by a doubling in arm, leg, third-finger, tail and body length in 5 months by Goblin and Blue Devil (tables 2 and 3).

The average IMI of 89 (n = 39 from tables 2–4) for infant aye-ayes is considerably larger than the 77 for an adult female and 81 for an adult male aye-aye (DUPC records). Sterling [3] reported a combined male-female IMI of 77 (n = 7) for wild aye-ayes on Nosy Mangabe. The larger IMI values for infants is indicative of the hind- and forelimbs being more nearly the same length (tables 2–4). The rate of growth for hind- and forelimbs was similar during the time the measurements were taken (tables 2–4). If both continued at the same rate and for the same length of time, then the adult IMI would be larger and more similar to that for infants and juveniles. Since the adult IMI is much smaller than the IMI for infants and juveniles, there has to be a difference in the rate of growth or in the duration of growth. As indicated in tables 2 and 3, the rate of growth was similar up to 8 or 9 months. It is possible but unlikely that the rate of growth would change during the final stages of growth. If it does not, then the only way to obtain the observed smaller IMI in adult aye-ayes is for the hindlimb to grow for a longer time than the forelimb [8].

Aye-ayes are quadrupedal, but the IMI values of 77–81 for these adult individuals are much larger than for other quadrupedal lemurs of similar body size, e.g. IMI values of 73 for adult female and 72 for adult male *Eulemur fulvus rufus* and 69 for adult female and 72 for adult male *Eulemur rubriventer* [9]. Larger IMI values indicate that the hindlimb and forelimb are more similar in overall length. Vertical clingers and leapers have smaller IMI values, e.g. an average of 68 (n = 34; range 60–70) for *Avahi laniger* and *Propithecus diadema edwardsi* from Ranomafana National Park [9]. Overdorff [10] reported that *E. rubriventer* (IMI = 69 f and 73 m) used clinging and leaping 50% of the time. Gebo [11] found that captive *E. fulvus rufus* (IMI = 73 f and 72 m) spent 34% of their time leaping. The much larger IMI values for adult aye-ayes suggest that they spend less of their time leaping. The IMI is probably not related to time spent on the ground. Sterling [3] reports that aye-ayes spent 25% of their time on the ground. Ring-tailed lemurs *(L. catta)* spend

Table 5. Average weights for adult aye-ayes at DUPC

Name	Sex	Average weight, g	n	Range, g
Endora	f	2,749	12	2,311–2,992
Morticia	f	2,434	13	2,257–2,642
Ozma	f	2,581	12	2,161–2,750
Samantha	f	2,301	43	1,780–2,475
Mephistopheles	m	2,638	14	2,202–2,774
Nosferatu	m	2,851	45	2,660–3,073
Poe	m	2,576	47	2,200–2,938

Males (n = 3) weighed 2,688 g (SD 144 g; n.s.), females (n = 4) 2,516 g (SD 192 g).

Table 6. The average body weights for females and the birth weights for their infants

Mother's name	Average weight, g	n	Infant's name	Birth weight, g
Endora	2,749	12	Blue Devil	136
Ozma	2,581	12	Goblin	108
Morticia	2,434	13	Cruella	102
Samantha	2,301	43	unnamed	90

more time on the ground (30–36% of their time [12]) but have an IMI of only 70 [13].

The aye-aye is one of the most endangered primates and one for which little information on its basic biology and life history variables has been available because they had not previously successfully reproduced in captivity. The captive births of five surviving aye-ayes at the DUPC and JWPT are major steps towards the preservation of this highly endangered primate family. These births and the subsequent growth and development of the infants provide valuable knowledge about a species whose biology is little known. Given that their appearance is so unusual, further study of their psychology, ecology and biology may produce additional surprises.

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Addendum

The fifth aye-aye infant (Merlin) was born at the DUPC on June 5, 1994. Endora is his mother, and Nosferatu is the father. A sixth infant (Calaban) was born on August 25, 1994. The infants, both males, weighed 232 g and 107 g, respectively.