BRIEF REPORT

Demographic Review of a Captive Colony of Callitrichids (*Callithrix kuhlii*)

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Although reports on colony demographics for a variety of callitrichid species are available in the literature, to date there has not been a detailed examination of Wied's black tufted-ear marmoset (*Callithrix kuhlii*). The purpose of this study is to present colony demographics for *C. kuhlii* from the University of Nebraska at Omaha's Callitrichid Research Center from 1991 to 2002. *C. kuhlii* are currently held in a number of zoological parks in the United States and abroad; however, the University of Nebraska at Omaha held the only breeding colony in North America. Here we report data on lifespan, sex ratio, litter size, and interbirth interval (IBI) for that captive breeding colony. Am. J. Primatol. 69:234–240, 2007. © 2006 Wiley-Liss, Inc.

Key words: demography; reproduction; callitrichids; interbirth interval; sex ratio

INTRODUCTION

The successful breeding and maintenance of primates in captivity depend on our knowledge about the reproductive parameters and ecology of a species. Often the lack of such knowledge precludes the successful rearing of infants and the formation of successful social groups. Callitrichidae have been maintained in captivity for biomedical research for decades [French et al., 1996; Gengozian et al., 1978; Rothe et al., 1986; Tardif et al., 2003; Wolfe et al., 1975]. The reproductive parameters of primates in the family Callitrichidae have been detailed [Gengozian et al., 1978; Rothe et al., 1986], and recommendations for successful breeding have been described [Tardif et al., 2003; Wolfe et al., 1975].

Documentation regarding the reproduction of marmosets has primarily focused on the common marmoset (*Callithrix jacchus*) [Tardif et al., 2003]. *C. jacchus* has been reported to breed seasonally in the wild, produce twins, and

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form cooperative breeding groups [Tardif et al., 2003]. However, reproductive parameters vary greatly among callitrichid genera. For example, *Leontopithecus* has been reported to produce one litter a year on average, with seasonal births in spring, summer, and fall months [French et al., 1996]. *Saguinus* is typically more difficult to maintain and breed in captivity, and typically produces 1.5 litters a year [Tardif et al., 1984; Wolfe et al., 1975].

Wied's black tufted-ear marmoset (*Callithrix kuhlii*) was only recently recognized as a true species [Marroig et al., 2004]. Once thought to be a hybrid of *C. penicillata* and *C. geoffroyi*, *C. kuhlii* is now recognized as a true species, as supported by morphological and molecular systematic data [Marroig et al., 2004]. *C. kuhlii* are found more rarely in captivity compared to *C. jacchus*. Although several studies have examined group formation, reproductive suppression, and infant care for *C. kuhlii* [Fite et al., 2003, 2005a,b; French et al., 1995; Nunes et al., 2000; Ross et al., 2004; Schaffner et al., 1995; Smith & French, 1997], no demographic reports are available for this species. In this paper demographic data regarding the average lifespan, litter size, sex ratio, and interbirth interval (IBI) for the only North American breeding colony of *C. kuhlii* are reported.

MATERIALS AND METHODS

Subjects

Sixteen *C. kuhlii* (eight males and eight females) were imported from the Centro Primatologia (CPRJ) breeding facility in Rio de Janiero, Brazil, in 1991 to be maintained at the University of Nebraska at Omaha's Callitrichid Research Center. These animals were captive-bred and were at least one generation removed from the wild-caught founders of the CPRJ population. All of the imported animals were reported to be unrelated.

The *C. kuhlii* were bred for noninvasive reproductive and social-behavior research until 2002. Information regarding pairing and housing status, breeding, and medical treatments was maintained with the use of ISIS software, including SPARKS (studbook data), ARKS (colony records), and MedARKS (medical history) for the colony for the years 1991 to 2002. In 2002 the American Zoological Association (AZA) developed a species survival plan for *C. kuhlii*. Breeding was discontinued at the University of Nebraska's Callitrichid Research Center due to the conservation and captive status of *C. kuhlii*.

The marmosets were maintained in family groups and siblings remained in the family for at least two sets of births unless that was precluded by aggression. Most adults were maintained as monogamous breeding units with offspring. However, for a set of experiments in 1994–1999, five families were maintained as polyandrous groups with offspring. Routine husbandry practices were designed to minimize as much as possible any disturbance to the normal day-to-day activities of the animals. For instance, we limited the animals' exposure to unfamiliar humans, and handled them only when it was necessary to administer veterinary care. Additionally, laboratory policy precluded the hand-rearing of any infants. The animals were housed in cages that measured at least $1.2 \times 0.9 \times 2.4$ m and were constructed of wooden frames and wire mesh walls. The cages contained natural branches, a nest tube, a removable transport cage, a feeding platform, and numerous enrichment devices. A 12 hr/12 hr light/dark cycle was controlled via automatic timers, with light onset occurring at 0800 hr. Visual access between groups was limited, but olfactory and auditory contact with two to three other family groups was available (for further details regarding animal husbandry and housing, see Schaffner et al. [1995]). Contraception in the colony included prostaglandin injections and ovariohysterectomy for females, and vasectomy for males. Animals that received such treatments were excluded from the analysis of reproductive parameters.

RESULTS AND DISCUSSION

Pairing and Breeding

Of the original 16 animals imported from CPRJ, four males and one female failed to contribute offspring to the next generation. Two males died prior to pairing and reproduction, and two males and one female paired but never produced offspring. Since the formation of the colony in 1991, the colony has produced five generations from the founders. A total of 284 animals were born in the facility.

Animals were paired when both the male and female were approximately 2 years of age. Decisions on pairing were based on the availability of a mate and the pedigree status of the potential mates. The average time between pairing and the production of the first viable offspring was 225.5 days (range = 150–510 days, n = 21). The average gestation time for *C. kuhlii* was previously reported as 143 ± 1.6 days [French et al., 1996], which is comparable to that reported for *C. jacchus* (145 ± 2.3 days) [Tardif et al., 2003].

The average breeding efforts of males and females, including the average age of reproduction, average lifespan of breeding animals, and the number of litters produced, are presented in Table I. Males and females did not differ significantly in average age of first siring/conception (t = 2.2, df = 23, n.s.), lifespan (t = 2.1, df = 7, n.s.), or number of litters produced (t = 2.0, df = 23, n.s.).

Lifespan

The average lifespan of animals that lived to weaning (at approximately 9 weeks of age) was 5 years and 6 months for males, and 5 years and 5 months for females. The oldest living male was 14 years and 1 month, while the oldest female was 16 years and 9 months. The ages of the founding animals were all verified by CPRJ records. The average lifespan of breeding animals was 7 years and 6 months for males, and 7 years and 5 months for females. The average lifespan reported is very similar to that of *C. jacchus* (6 years in captivity) [Tardif et al., 2003].

Sex-Ratio Analysis

A number of primate species, including marmosets and tamarins, have been noted to produce sexually skewed litters, with one sex typically having better

TABLE I. Reproductive Demographics of *Callithrix kuhlii*

Demographic variables	Male	Female	*Callithrix jacchus*[c]
Number of breeding adults	24[b]	26	–
Average age of first reproduction	2.7	3.3	2.49
Youngest age to sire/conceive infants	1.0	1.4	0.9
Oldest age to sire/conceive infants	13.7	12	–
Oldest age at first reproduction	6.3	7.8	–
Average ♯ of litters produced	5.1	4.7	4
Average lifespan of breeding animal[a] (n)	8.7 (8)	7.4 (12)	5.99

[a]Average lifespan of a breeding animal was calculated only from animals that were deceased.
[b]All ages are years.
[c]Data summarized in Tardif et al. [2003].

TABLE II. Survivorship of *Callithrix kuhlii* Infants

	Male	Female	Unknown	Total
Number of infants born	134	101	44	279
Percent of births	48	36.2	15.8	100
Number surviving to weaning	59	57	0	116
Percent surviving of all births	21.1	20.4	0	41.6
Percent of each sex surviving	44	56.4	0	–

survivorship. In the majority of callitrichid studies to date, male infants had better survivability to weaning than female infants [French et al., 1996; Wolfe et al., 1975]. The number of births in the colony from 1991 to 2002, the percentage of births that were male, and the percentage of male infants that survived to weaning are presented in Table II. A χ^2 analysis revealed that the male birth rate was significantly higher than the 50:50 ratio expected for births ($\chi^2 = 4.6$, df = 1, $P < 0.05$). However, the percentage of surviving infants that were male did not differ significantly from 50:50 ($\chi^2 = 0.016$, df = 1, n.s.) because the number of males that did not survive to weaning was significantly higher than the number of females ($\chi^2 = 8.08$, df = 1, $P < 0.01$). Therefore, while the sex ratio of infants born in the colony is male-biased, the infants that survived to weaning represent the expected 50:50 ratio.

We analyzed the sex ratio of twin sets to determine whether male-female twin sets were less likely to occur in the colony than same-sex twins. Based on inheritance of sex chromosomes, male-female twins should be twice as likely as same-sex twins to occur, resulting in a ratio of 25% male-male, 50% male-female, and 25% female-female. The sex ratios of the twin litters did differ significantly from the 25%-50%-25% or 1:2:1 ratio expected ($\chi^2 = 7.28$, df = 2, $P = 0.04$). However, whereas the presence of male-female twins was very similar to the predicted value (52 predicted, 49 actual), the predominance of male-male twins (26 predicted, 37 actual) and the lack of female-female twins (26 predicted, 18 actual) differed from predicted values.

Litter Size

Although the modal litter size of callitrichids in captivity and field studies is two, a number of captive colonies have noted increases in the litter size over time [Hampton et al., 1978; Rothe et al., 1986; Tardif et al., 1986]. This increasing trend to produce larger litters has been cited as an effect of increased fatty diets, and less activity for the animals. Females with increased body weight and fat resources tend to produce larger litters [Rothe et al., 1986; Tardif & Bales, 2004; Tardif & Jacquish, 1997]. Additionally, increasing female age at parity has been associated with larger infant birth weights, and females that are larger at birth have larger litters, contributing to the trend of increased litter size with longer colony age [Tardif & Bales, 2004]. *C. kuhlii* does not seem to follow this trend in captivity. The range in litter size for *C. kuhlii* was one to five individuals at birth, and the modal litter size was two. While a number of females gave birth to litters larger than twin sets, there was no overall change in the litters produced in the colony over time. Female parity was also not related to litter size, with primiparous mothers giving birth to 2.1 infants on average, and multiparous mothers giving birth to 2.2 infants on average. Even mothers that gave birth to 12 litters averaged a litter size of 1.5.

TABLE III. Interbirth Intervals in *Callithrix kuhlii*

Litter size	Singleton	Twins	Triplets		
	174.8+8.3[a]	158+3.6	164.3+5.9		
	(146–246)[b]	(142–212)	(146–269)		
	n = 8	n = 43	n = 16		
Infants nursed	Zero	One	Two		
	163.7+4.9	155.2+6	162.5+4.4		
	(142–246)	(145–182)	(147–269)		
	n = 24	n = 16	n = 29		
Helpers present	One	Two	Three	Four	Five
	163.4+5.6	156.5+6.5	162.1+6.3	168.3+10	162+9.4
	(147–269)	(146–205)	(146–209)	(145–246)	(147–203)
	n = 19	n = 15	n = 15	n = 6	n = 7

[a]Mean+SEM.
[b]Range.

IBI

We analyzed 69 IBIs. The modal IBI for the colony was 150 days, with a median value of 152 days, which is very similar to the median value of IBIs (157) reported for *C. jacchus* [Box & Hubrecht, 1987; Poole & Evans, 1982; Windle et al., 1999]. Several analyses of IBI in *C. jacchus* revealed a delay in production of the next litter following the production of triplets or larger litters [Box & Hubrecht, 1987; Poole & Evans, 1982]; however, we found that IBI did not vary according to litter size in *C. kuhlii* ($F_{4,63} = 1.01$, n.s.; Table III). Additionally, although studies of other callitrichid colonies have reported longer IBIs due to the number of infants nursed, and a decrease in IBI due to the presence of helpers [Baker & Woods, 1992; Windle et al., 1999], we found that in *C. kuhlii* the IBI did not vary according to the number of infants nursed ($F_{2,65} = 0.768$, n.s.) or the number of helpers present ($F_{7,60} = 0.232$, n.s.; Table III).

CONCLUSIONS

By examining callitrichids from a captive breeding colony, we can gain more complete knowledge about their breeding activities, pedigree status, health, and behaviors. Our analysis of *C. kuhlii* demographics demonstrates that *C. kuhlii* does not differ dramatically from *C. jacchus* in a number of its breeding habits and behaviors. *C. kuhlii* individuals live an average of $5^1/_2$ years, which is very similar to the average age for *C. jacchus* (6 years) maintained in captivity [Gengozian et al., 1978; Tardif et al., 1984, 2003]. Additionally, the percentage of infants that survive to weaning is very similar to that reported for other callitrichid species (the majority of infants do not survive to weaning in captivity or in the wild) [Gengozian et al., 1978; Kirkwood et al., 1983; Savage et al., 1996; Stephens, 1989; Tardif et al., 1984, 2003]. While one might suspect that such closely related species would exhibit similar demographic outputs, Callitrichidae as a family is known for its variety in reproduction and parental care. Previous studies of callitrichids have described a great deal of variability in the number of infants produced and raised due to variables such as the number of members of the social group, and the resources available to the mother [Tardif et al., 2003]. In general, while our analysis of the demographic statistics, along with previous behavioral data [French et al., 1995] for the colony, suggests that *C. kuhlii* does not differ greatly from the descriptions of other *Callithrix* species, this analysis offers the first demographic data of a *Callithrix* species other than *C. jacchus*. This analysis of demographic data for *C. kuhlii* will provide information to future researchers that they can use to make predictions about reproductive investment, whereas in the past researchers have had to rely on data from a single species of *Callithrix*. Further, while the captive distribution of *C. kuhlii* in the United States was once limited to one breeding colony, 15 zoological associations have now begun to house this species. The current demographic data for *C. kuhlii* provide a baseline for future research and management of this species, which belongs to a group that is well known for its behavioral and reproductive variability.

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REFERENCES

Baker AJ, Woods F. 1992. Reproduction of the emperor tamarin (*Saguinus imperator*) in captivity, with comparisons to cotton-top and golden lion tamarins. Am J Primatol 26: 1–10.

Box HO, Hubrecht RC. 1987. Long-term data on the reproduction and maintenance of a colony of common marmosets (*Callithrix jacchus jacchus*) 1972–1983. Lab Anim 21: 249–260.

Fite JE, French JA, Patera K, Hopkins E, Rukstalis M, Jensen H, Ross CN. 2003. Nighttime wakefulness associated with infant rearing in *Callithrix kuhlii*. Int J Primatol 24:1267–1280.

Fite JE, Patera KJ, French JA, Rukstalis M, Hopkins EC, Ross CN. 2005a. Opportunistic mothers: female marmosets (*Callithrix kuhlii*) reduce their investment in offspring when they have to, and when they can. J Hum Evol 49:122–142.

Fite JE, French JA, Patera KJ, Hopkins EC, Rukstalis M, Ross CN. 2005b. Elevated urinary testosterone excretion and decreased maternal caregiving effort in marmosets when conception occurs during the period of infant dependence. Horm Behav 47: 39–48.

French JA, Schaffner CM, Shepherd RE, Miller ME. 1995. Familiarity with intruders modulates antagonism toward outgroup conspecifics in Wied's black tufted-ear marmoset (*Callithrix kuhlii*). Ethology 99: 24–38.

French JA, Pissinatti A, Coimbra-Filho AF. 1996. Reproduction in captive lion tamarins (*Leontopithecus*) seasonality, infant survival, and sex ratios. Am J Primatol 39: 17–33.

French JA. 1997. Proximate regulation of singular breeding in callitrichid primates. In: Solomon NG, French JA, editors. Cooperative breeding in mammals. Cambridge: Cambridge University Press.

Gengozian N, Batson JS, Smith TA. 1978. Breeding marmosets in a colony environment. Primatol Med 10:71–78.

Hampton SH, Gross MJ, Hampton JK. 1978. A comparison of captive breeding performance and offspring survival in the family *Callitricidae*. Primatol Med 10:88–95.

Kirkwood JK, Epstein MA, Terlecki AJ. 1983. Factors influencing population growth of a colony of cotton-top tamarins. Lab Anim 17: 35–41.

Marroig G, Cropp S, Cheverud JM. 2004. Systematics and evolution of the *jacchus* group of marmosets (Platyrrhini). Am J Phys Anthropol 123:1–22.

Nunes S, Fite JE, French JA. 2000. Variation in steroid hormones associated with infant care behaviour and experience in male marmosets (*Callithrix kuhlii*). Anim Behav 60: 857–865.

Poole TB, Evans RG. 1982. Reproduction, infant survival and productivity of a colony of common marmosets (*Callithrix jacchus jacchus*). Lab Anim 16:88–97.

Ross CN, French JA, Patera K. 2004. Intensity of aggressive interactions modulates testosterone in male marmosets. Phys Behav 83: 437–445.

Rothe H, Kong A, Darms K, Siess M. 1986. Analysis of litter size in a colony of the common marmoset (*Callithrix jacchus*). Z Saugetier 52:227–235.

Savage A, Giraldo LH, Sotto LH, Snowdon CT. 1996. Demography, group composition, and dispersal in wild cotton-top tamarin (*Saguinus oedipus*) groups. Am J Primatol 38: 85–100.

Schaffner CM, Shepherd RE, Santos CV, French JA. 1995. Development of heterosexual relationships in Wied's black tufted-ear marmosets. Am J Primatol 36:185–200.

Smith TE, French JA. 1997. Social and reproductive conditioned modulate urinary cortisol excretion in black tufted-ear marmosets. Am J Primatol 42:253–267.

Stephens ME. 1989. Tamarins: alpha female, queen bee, or white rat? Int J Primatol 10: 115–121.

Tardif S, Richter CR, Carson RL. 1984. Reproductive performance of three species of Callitrichidae. Lab Anim Sci 34:272–275.

Tardif SD, Carson RL, Clapp NK. 1986. Breeding performance of captive-born cotton-top tamarin (*Saguinus oedipus*) females: proposed explanations for colony differences. Am J Primatol 11:271–275.

Tardif SD, Jacquish CE. 1997. Number of ovulations in the marmoset monkey (*Callithrix jacchus*): relation to body weight, age, and repeatability. Am J Primatol 42: 323–329.

Tardif SD, Smucny DA, Abbott DH, Mansfield K, Schultz-Darken N, Yamamoto ME. 2003. Reproduction in captive common marmosets (*Callithrix jacchus*). Comp Med 53: 364–368.

Tardif SD, Bales KL. 2004. Relations among birth condition, maternal condition, and postnatal growth in captive common marmoset monkeys (*Callithrix jacchus*). Am J Primatol 62:83–94.

Windle CP, Baker HF, Ridley RM, Oerke A-K, Martin RD. 1999. Unrearable litters and prenatal reduction of litter size in the common marmoset (*Callithrix jacchus*). J Med Primatol 28:73–83.

Wolfe LG, Deinhardt F, Ogden JD, Adams MR, Fisher LE. 1975. Reproduction of wild-caught and laboratory-born marmoset species used in biomedical research (*Saguinus* sp. *Callithrix jacchus*). Lab Anim Sci 25: 802–881.