

Reproductive parameters of a captive colony of capuchin monkeys (*Cebus apella*) from 1984 to 2006

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Abstract This paper presents the results of a demographic analysis of 22 years of data recorded on a colony of tufted capuchin monkeys (*Cebus apella*) in captivity at the CNR Primate Centre (Rome, Italy). Information is provided on reproduction, sex ratio, inter-birth interval (IBI), seasonality, and body weight. From 1984 to 2006, 46 live births were recorded. There were births in almost all months of the year, but a higher frequency was observed during spring and summer (71.1%). The sex ratio was 1:1 M:F for newborns and 1:1.06 M:F for surviving offspring. At birth, infants' average weight was 238.13 ± 37.51 g, i.e. 250 ± 56.79 g for males and 231 ± 26.08 g for females. Age at first birth for females ranged from 4.9 to 7 years ($n = 9$), while males achieved first paternity between the ages of 5 and 9.2 years ($n = 6$). Only one pair of twins was recorded during this period. For females, the mean IBI was 17.88 ± 1.84 months, when they reared infants, and 12.70 ± 1.73 months, when they did not rear offspring. Infant mortality within the first 2 months was 28.3%.

Keywords Demography · Reproduction · Capuchin monkey · *Cebus apella* · Inter-birth interval

Introduction

Information on the demographic and reproductive parameters of wild and captive primates is crucial for assessing their overall condition. In the wild, this information allows us to become better acquainted with the species, to evaluate population fluctuations in a defined area and over time, and to observe an animal's adaptive strategies in the face of environmental change. Thus, it is possible to evaluate the status of a given population (i.e. whether it is expanding or at risk of extinction, etc.), and ensure adequate management and conservation. In captivity, these data enable a better understanding of the biology, ecology and behaviour of hosted species, especially those aspects that are difficult to study in the wild. Consequently, it is possible to introduce management programs that ensure the animals' welfare and reflect the real needs of the species. Long-term data on several species have been reported in both free-ranging and captive conditions (Garber et al. 1993; Ha et al. 2000; Lynch and Rimoli 2000; Koyama et al. 2001; Setchell et al. 2002; Fedigan and Jack 2004; Strier et al. 2006).

In recent years, New World monkeys—the species most likely to be found in zoos—have been used increasingly in biomedical and ethological research. Nevertheless, long-term data on reproductive and demographic parameters in these monkeys is still relatively scarce compared to the large quantity of data available on the catarrhines, particularly for species like *Cebus apella* (for captive colonies: see Nagle and Denari 1982; Patiño et al. 1996; Fragaszy and Adams-Curtis 1998; for wild populations: see Di Bitetti and Janson 2001).

This paper presents the demographic data (recorded over 22 years) of a colony of tufted capuchin monkeys born and maintained in captivity at the Primate Centre of the Institute for Cognitive Science and Technologies of the

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National Research Council (CNR) in Rome (Italy). Data refer to reproductive parameters such as age of first maternity and paternity, number of offspring, infant survival within 2 months, sex ratio, reproductive seasonality, and inter-birth intervals (IBI). This study contains important information that could contribute to the health and well-being of New World monkeys held in captivity as well as help increase captive populations, thus minimising the need to take animals from the wild.

Methods

The Primate Centre of CNR is located in the Bioparco of Rome. When the colony was founded in 1984, it consisted of seven monkeys (three males and four females). Briefly, from 1984 to 2006 there were 46 births, 8 monkeys were brought in from other centres, 15 were transferred to other centres, and 17 died.

The monkeys in our centre have always been housed in social groups in indoor–outdoor cages (see Wirz et al. 2008); however, the number of social groups and the number of individuals in each group has changed during the period considered.

Monkeys are fed with monkey chow offered *ad libitum*. In addition, to increase the variety of food and to prolong the time spent searching for food and consuming it, the animals are given seasonal fruits and vegetables every afternoon. Moreover, twice a week they receive an extra meal of cheese mixed with eggs, bran, oats, sugar, salt, vitamins, and minerals. Water is always available.

Data relating to births, deaths, movement between social groups, diseases, aggressions, etc., are recorded daily. The animals' health is checked weekly by a veterinarian, and the data are recorded. Pregnancies are determined by visual inspection of the mother and/or palpation of the abdomen during routine veterinary checks. Moreover, subjects are captured and anesthetized at least once a year for veterinary inspection. During this health examination, haematological data, weight, and rectal temperature are recorded (Riviello and Wirz 2001; Wirz et al. 2008). Moreover, the monkeys are tested for tuberculosis. Fecal samples and rectal swabs are also collected for bacteriological and parasitological tests.

The tufted capuchin monkeys hosted at our centre are used only for non-invasive behavioural studies. These focus on cognitive capacity development (tool use, spatial orientation, handedness and perspective taking: Poti 2000; De Lillo et al. 2005; Spinozzi et al. 2004a, b) and behavioral biology (sexual and alimentary: Fragaszy et al. 2004; Drapier et al. 2003; Addessi and Visalberghi 2004; Addessi et al. 2005). All research protocols have been approved by the Italian Ministry of Health and are in accordance with Italian legal requirements and institutions.

At present, the colony consists of 29 monkeys, 10 adult males and 14 adult females (>4 years) and 2 juvenile males, and 3 juvenile females (1–4 years), divided into four social groups.

Data collection

Throughout the study, the following information was recorded daily for each animal on data sheets developed *ad hoc*: births, sex, deaths, transfers, illnesses, medical treatments, aggression, check ups, and veterinary operations. Maternal and paternal genealogy were also recorded. When more adult males were present in the social group, paternity was determined by genetic analysis. For the five animals that were either donated to our centre or confiscated by airport police and brought to us, birth dates were estimated by the health team.

We assumed a gestational period of 5 months, as reported by Nagle and Denari (1982) for this species.

For reproductive seasonality, we examined the overall annual distribution of births in the colony using the birth dates of all offspring ($n = 46$) born between the inception of the colony (1984) and September 2006.

The χ^2 test was performed to determine the differences between deaths of infants delivered by dominant and subordinate females. Furthermore, this test was used to compare the sex ratios of newborns and of surviving offspring and the differences between births occurring in spring/summer and those occurring in autumn/winter.

We calculated inter-birth intervals (IBI) as the number of months between births. IBI were analysed using the data of four females that had given birth to two or more infants. We excluded from the IBI calculation the data of those females ($n = 6$) that did not constantly have reproductive males in their group or of those females undergoing cycles of contraceptive therapy.

To evaluate whether a difference occurred in females' IBI when they reared or did not rear infants, we applied Wilcoxon signed-ranks test. The statistical analysis took into consideration only the three females for which we had collected data in both conditions, i.e. IBI after infant survival and IBI after infant loss. The fourth female was excluded from the statistical analysis since data of IBI after infant loss were not available as she always reared her infants. P values ≤ 0.05 were considered significant for all performed tests.

Results

Since 1984, there have been 45 known pregnancies and 46 births (one pair of twins), therefore the average birth rate was 2.09 per year. Of all newborns, 33 survived (71.7%)

and 13 died (28.3%) (Table 1). Of the 13 dead infants, 76.9% died within the first 3 days ($n = 10$), 15.4% died at 10 days old ($n = 2$), and 7.7% at 2 months old ($n = 1$) (Table 1). The sex ratio was 1:1 M:F for newborns, 1:1.06 M:F for surviving offspring, and 1.2:1 M:F for dead offspring (Table 1). The χ^2 test showed no statistically significant differences in the sex ratio ($\chi^2 = 0$, $P > 0.05$). The composition of social groups to which dead infants belonged varied from a minimum of two individuals (father and mother, or mother with another adult female) to a maximum of six individuals (father and mother and other individuals of different sex and age). Six of the dead infants were born from dominant and seven from subordinate females; the χ^2 test showed no statistically significant differences between the two groups of dead infants ($\chi^2 = 0$, $P > 0.05$). Of all deaths, six were due to maternal neglect (46.1%) by four females (Punk, Rosita, Roberta, Viola), four to attack by cage mates (30.8%), and three (23.1%) to unknown reasons.

There were births in almost all months of the year, but a higher frequency was observed during spring and summer (71.1%) as can be seen in Fig. 1. The χ^2 test showed no statistically significant differences between the births occurring in spring/summer and those occurring in autumn/winter ($\chi^2 = 16.98$, $P > 0.01$).

At birth, the average weight of infants was 238.13 ± 37.51 g ($n = 8$), specifically, 250 ± 56.79 g for males ($n = 3$) and 231 ± 26.08 g for females ($n = 5$). The lowest weight for a live-born infant was 185 g, and the highest 290 g. The Mann–Whitney U -test showed no statistically significant differences between the weights of males and females weights ($U = 5$, $P > 0.05$).

In our colony, 10 out of 15 females of reproductive age had infants during this study (Table 2). At first pregnancy

one of the ten females was dominant, eight were subordinate, and for one we had no data because she came to our centre with her offspring. With the exception of this last female whose previous history is unknown, all the others lived in multi-female groups. Their age at first maternity ranged from 4 years and 9 months to 7 years.

As shown in Table 2, nine males reproduced during this study. At their first paternity, five were dominant (three belong to multi-male groups and two to single-male groups), and two were subordinate (both living in multi-male groups). We had no information about social rank and age at first paternity for the other two males, because they came from other centres. Ages of males at first established paternity ranged from 5 years to 9 years and 2 months. In one case, Cognac, first paternity was ascertained at 16 years and 3 months of age (Table 2). Cognac always belonged to a large social group within which he was subordinate. Only when the group was split in two for management reasons, did Cognac became dominant in his new group and reproduce.

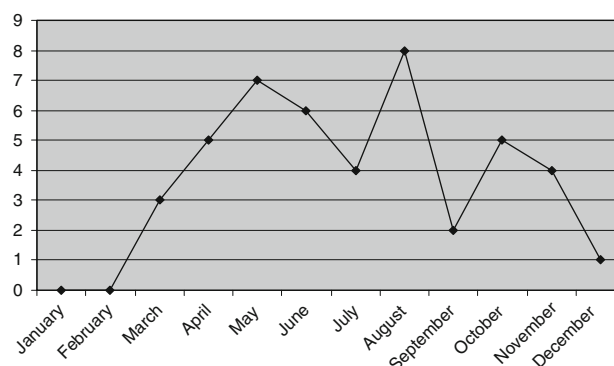


Fig. 1 Trend of births

Table 1 Births and infant mortality from 1984 to 2006

Name of mother	No. of newborn (M/F)	No. of surviving offspring (M/F)	No. of dead offspring within 3 days (M/F)	No. of dead offspring at 10 days old (M/F)	No. of dead offspring at 2 months old (M/F)
Punk	12 (4/8)	7 (2/5)	3 (1/2)	1 (0/1)	1 (1/0)
Roberta ^a	9 (4/5)	6 (3/3)	2 (0/2)	1 (1/0)	0
Consuelo	6 (6/0)	6 (6/0)	0	0	0
Paquita	5 (2/3)	4 (1/3)	1 (1/0)	0	0
Rosita	3 (2/1)	2 (1/1)	1 (1/0)	0	0
Pilar	4 (2/2)	2 (1/1)	2 (1/1)	0	0
Viola	3 (2/1)	2 (1/1)	1 (1/0)	0	0
Robinia	2 (1/1)	2 (1/1)	0	0	0
Pacaja	1 (0/1)	1 (0/1)	0	0	0
Penelope	1 (0/1)	1 (0/1)	0	0	0
Total	46 (23/23)	33 (16/17)	10 (5/5)	2 (1/1)	1 (1/0)

M/F Number of males/number of females

^a Only female to have twins

Table 2 Age and rank at first pregnancy and at first established paternity

Name of mother	Rank	Age at first pregnancy	Name of father	Rank	Age at first established paternity
Punk	a	a	Rosso	a	a
Roberta	S	5 years and 3 months	Zapotec	a	a
Consuelo	S	5 years ^b	Cammello	D	9 years
Paquita	S	4 years and 9 months	Narciso	D	6 years ^b
Rosita	D	5 years ^b	Patè	D	8 years and 3 months
Pilar	S	7 years ^b	Pepe	S	9 years and 2 months
Viola	S	6 years ^b	Pillow	D	5 years
Robinia	S	6 years and 10 months	Copì	S	6 years and 7 months
Pacaja	S	6 years and 1 month	Cognac	D	16 years and 3 months
Penelope	S	5 years and 2 months			

S subordinate, D dominant

^a Adults came from another centre; previous history unknown

^b Estimated age

Table 3 Inter-birth intervals (IBI), in months

Name of mother	Mean IBI after infant survival	Mean IBI after infant loss	Range of IBI after infant survival	Range of IBI after infant loss
Punk	20 (<i>N</i> = 2)	11.44 (<i>N</i> = 9)	14–26	8–14
Roberta	18 (<i>N</i> = 2)	14.67 (<i>N</i> = 3)	15–21	8–23
Consuelo	15.5 (<i>N</i> = 4)	–	13–23	–
Paquita	18 (<i>N</i> = 2)	12 (<i>N</i> = 1)	16–20	12
Mean value	17.88	12.70		

N number of IBIs

A total of 23 IBI were analysed for four females (Table 3). The mean IBI was 17.88 ± 1.84 months (range: 13–26 months; *n* = 10 IBI) for infant-nursing females, and 12.70 ± 1.73 months (range 8–23 months; *n* = 13 IBI) for non infant-nursing females (Table 3). The Wilcoxon signed-ranks test showed no statistically significant differences between the IBI data after infant survival and after infant loss (*P* = 0.109).

Discussion

Tufted capuchin monkeys can reproduce easily in captivity, females usually carry pregnancies to term successfully, and during their reproductive life they have several maternities (Fragaszy and Adams-Curtis 1998). In our case, of the ten females that reproduced, eight were multiparous and two primiparous. All known pregnancies were full term. The sex ratio at birth, close to 1:1 (M:F), is in accordance with that reported by Di Bitetti and Janson (2001) in the wild. We assume that the five females that did not reproduce were sterile because, although of reproductive age, not

treated with any contraception therapy, and mating with fertile males, they never became pregnant. Moreover, it is not possible to correlate this reproductive failure with their age, rank, social group or personal history, because they changed social group and rank during the period of the study.

In our colony, infant mortality occurred mainly within the first 3 days after birth, and decreased drastically within the first 2 months of life. After this age, infant mortality did not occur. Although the cause of death could not always be determined with certainty, maternal neglect and attacks by other members of the social group seemed to be the main causes, independent of the mother's rank. The abandonment of infants can be determined either by stress or by inadequate maternal experience. In fact, social conditions within the groups can cause stress for the mother, making it difficult for her to raise her offspring; social tension can also be the cause of trauma, accidental or not, leading to infant death. Abandonment due to inexperience of the mother might not occur in succeeding pregnancies. We noticed that, independent of their rank, several females in our colony that had neglected infants at their first

pregnancy reared their offspring properly after acquiring more experience.

It is not clear how this improvement is achieved, but it seems likely that the age of the female and the presence of other mothers with infants in the group might be contributing factors. The case of Punk, a dominant female, is illustrative; she had always lost infants and started rearing them only when another female of the same social group delivered and reared her own infants.

Our data indicate attacks by other individuals of the social group as the second most frequent cause of infant death. Dead infants showed deep bites involving vital organs. These socially inflicted trauma injures to young infants were restricted to the first 10 days after birth; it is possible that after this period the mother–infant relationship strengthened and mothers became more capable of defending their offspring and avoiding social conflicts.

There were births throughout the year, but the highest numbers of births were in spring and summer, in accordance with what was observed in the wild by Di Bitetti and Janson (2001), and in captivity by Patiño et al. (1996) and Bicca-Marques and Gomes (2005). In particular, we found that most births occurred from April to September, in agreement with findings by Welker et al. (1992) in a colony of captive *C. apella*, in which 86% of births occurred from May to September. Seasonal reproduction is a complex issue for primates such as capuchins, and could be linked to several factors. Di Bitetti and Janson (2000, 2001) asserted that, in wild Neotropical primates, births occur during the period coinciding with the season of highest availability of fruits and insects (spring and summer). In our colony, the quality and quantity of the diet is similar throughout the year. Therefore, seasonal changes in food cannot be responsible for triggering reproductive events, otherwise births would have been more evenly distributed throughout the year in captive settings, as suggested by Bicca-Marques and Gomes (2005). According to some authors, photoperiod and solar radiation might explain breeding seasonality (Patiño et al. 1996; Di Bitetti and Janson 2001; Bicca-Marques and Gomes 2005). Other authors suggest that, in capuchin monkeys, seasonal variation in male fertility due to changes in testosterone levels or testicular volume could be the determining factor (Lynch et al. 2002; Guimaraes et al. 2003). This hypothesis could explain the marked decrease in births observed in our colony in the winter months.

The age range of adult females at the time of their first delivery was comparable to that reported by Fragaszy and Adams-Curtis (1998): 4.9–7 years (our colony) vs 4.7–6.6 years (their colony). Most females that reproduced were subordinate, probably because in some social groups dominant females were under a birth control program and in other groups dominant females were likely sterile.

The age of adult males at the birth of their first offspring depended greatly on the social context and on their position in the hierarchy. The difference in paternal ages recorded for the males in our colony may have been due to social tensions or to the presence of a dominant male who controlled the mating of other subordinate males. Cognac's advanced paternity age (over 16 years) due to the presence of a dominant male in his social group, supports this idea. It was only when the hierarchy changed and he became the alpha male that he had the opportunity to mate with every female, and become a father.

In monkeys, which normally give birth to one infant at a time, age at first birth, spacing between successive births and infant survivorship are the most important determinants of fecundity. Intra-specific variability in IBI has been attributed to many factors, including survival of the previous infant (Fedigan and Rose 1995; Lynch and Rimoli 2000; Littleton 2005; Cui et al. 2006), lactation/sucking period (Cui et al. 2006), age, and rank of the mother (Setchell et al. 2002). In our colony, whether or not females rear their infants successfully has a strong influence on IBI. We found interesting differences in IBI when comparing data recorded after infant survival and after infant loss. However, such differences were not statistically significant, due to the low number of females considered. Our data show a wide range of variation in IBI values after infant loss. This could depend on conditions of psycho-physical stress in the mothers. For instance, the interval of 23 months between the first and second pregnancy of Roberta can be explained by stress due to the negative outcome of the first maternity when she delivered twins that died in the first 24 h. When infants are reared by mothers, our mean IBI value is lower than that reported by other authors [20 months in captivity (Fragaszy and Adams-Curtis 1998; Recabarren et al. 2000), and from 22 to 25 months in the wild (Robinson and Janson 1987; Lynch and Rimoli 2000)]. However, in the absence of lactation, our mean IBI value is closer to data observed in the wild [11.2 months (Lynch and Rimoli 2000)].

The short IBI values we recorded are probably due to the very good health of our colony, and to the wide choice and availability of fresh food throughout the year.

To summarise, we found:

- The age of females at first maternity ranged from 4.9 to 7 years, while the age of males at first paternity ranged from 5 to 9.2 years
- Of all newborns 71.7% survived and 28.3% died
- Infant mortality occurred mainly within the first 3 days after birth, and decreased drastically within the first 2 months of life. After this age, infant mortality did not occur. The main causes of infant mortality were social conflicts and/or maternal stress

- The highest frequency of births (71.1%) was observed during spring and summer
- The mean IBI for infant-nursing females was 17.88 months and for non infant-nursing females was 12.70 months.

In conclusion, we believe that our investigation increases the knowledge on the reproductive parameters of Neotropical species, in particularly in *Cebus apella*, and it shows that long-term studies are essential for better understanding demography of non-human species, in order to ensure an adequate management in captivity.

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