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Comparison of indoor and captive, free-roaming management in golden-headed lion tamarins (Leontopithecus chrysomelas) at Zürich Zoo

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Abstract

Traditional husbandry practices for the public display of Callitrichidae *involve strict separation of animals and public. An important consideration for the evaluation of such management is the occurrence of health problems and potential zoonotic risks. This study compared animal data and veterinary records from a captive, free-roaming population of golden-headed lion tamarins (*Leontopithecus chrysomelas*) with a population housed under indoor management. The captive, free-roaming group grew significantly faster than the indoor-housed group, as less animals died and offspring were more successfully weaned. No differences in the causes of death were detected between the two husbandry practices. However, bacterial diseases were most common and diagnosed significantly more often under indoor management. This study suggests that the captive, free-roaming management of golden-headed lion tamarins can be conducive to increased reproductive success, improved health and improved welfare. Therefore, current husbandry recommendations for captive, free-roaming conditions were supported by the findings of the present study as a valuable housing practice where health regulations and proper husbandry parameters permit.*

Keywords: *animal welfare, disease, golden-headed lion tamarin, husbandry, reproduction, zoonosis*

Introduction

Callitrichidae are popular New World primates in zoological collections. These small species of primate are housed and bred successfully in relatively small enclosures in research institutions (Buchanan-Smith *et al* 2004; Prescott & Buchanan-Smith 2004). Conversely, many modern zoological institutions attempt to provide callitrichid groups with optimal enclosure space and environmental conditions to promote a full range of naturalistic behaviours, social interactions, and locomotion patterns (Carroll 2002). Most collections in temperate climates are housed indoors in order to provide adequate climatic conditions throughout winter months. During summer, a smaller outdoor enclosure might be provided when temperatures allow. In addition, traditional husbandry practices for the public display of *Callitrichidae* involve a strict separation of animals from the public. Despite recommendations from most authors to provide callitrichids with a warm environment, different species maintained outdoors in temperate climates have, on occasion, proven remarkably tolerant of low temperatures if provided with suitable shelter. Various species were, for example, able to remain outdoors without significant health problems in various locations throughout the UK and the Channel Islands throughout the entire winter (Mallinson 1977; Price *et al* 1989).

Many of the general health and medical management considerations that apply to caring for non-human primates in captivity are directly applicable to *Callitrichidae*. Various infectious and non-infectious diseases are reported for golden-headed lion tamarins (*Leontopithecus chrysomelas*) in the literature (Montali & Bush 1999). Diarrhoea is the most common medical problem, with the cause often being multifactorial and related to changes in diet, stress, parasites, and bacterial infections with *Escherichia coli* and *Salmonella*, *Shigella*, *Klebsiella*, and *Campylobacter* spp. Other common health problems seen in captivity that are responsible for significant morbidity are Wasting Marmoset Syndrome (WMS) and dystocias (Montali & Bush 1999). It is recommended that outdoor-housed callitrichids, which might come into close contact with humans and especially children, be vaccinated against measles and tetanus. Human cold sores, caused by the *Herpes simplex* virus, are extremely dangerous to marmosets and tamarins and may cause fatal encephalitis (Hatt *et al* 2004). High levels of iron in captive diets can lead to callitrichids developing hepatic haemosiderosis or haemochromatosis, with increased mortality (Miller *et al* 1997).

Management programmes that eliminate or minimise chronic stress contribute to the health and well-being of the animals, and therefore reduce the risk of shedding

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pathogens. The goal of the current study was to recognise differences in animal welfare, health status and the risk of disease transmission between a group of captive, free-roaming golden-headed lion tamarins in comparison with a group kept under traditional indoor management.

Materials and methods

The current study involved 37 golden-headed lion tamarins bred and housed at Zürich Zoo, Switzerland. Between 1991 and 1999, Group A was kept under captive, indoor management which entailed indoor housing all year round and animals being separated from the public by glass windows. Group size varied between two and five animals and involved 14 individuals. The group had no visual or audible contact with other groups of golden-headed lion tamarins or other species of callitrichids. Available living space was 36 m^3 (6 × 3 × 2 m; length × width × height) and enclosures were equipped with natural soil, plants, additional climbing structures and nest boxes. In addition, a 12 m^3 (4 × 1 × 3 m) outdoor, wire enclosure was available when temperatures permitted from May to September. Room temperature was maintained between 21 and 26°C and 50–70% humidity.

In the period from 1999 to 2006, Group B was housed under captive, free-roaming conditions. A small mixed indoor/outdoor wire cage (4 × 1 × 3 m; 12 m^3), equipped with nest boxes and climbing structures for feeding and housing at night, was accessible at all times. The system facilitated separation of animals and visual health inspection on a daily basis. Animals under captive, free-roaming conditions were kept in the centre of the zoo with free access to the zoo grounds during warmer periods (March to November) of the year. The average range size was approximately 2,500 m^2. During winter (December to February), animals were housed under the traditional management as described above for Group A. After the introduction of the free-roaming management system, physical examinations were carried out twice a year — at the beginning and end of the indoor period — to monitor animals' health status. Group size varied from 2 to 12 animals, and involved 23 individuals. Data records of 1,836 animals from the international golden-headed lion tamarin studbook were used for comparisons: considered animals were born between 1988 and 2006 (Galbusera 2008).

In all, 28 animals were born at the facility, eight under traditional management and 20 under free-roaming conditions. Age range was between 0 and 14 years and both study groups consumed the same diet throughout the study period. Breeding animals under traditional management included 1–2 males in the age between 2 and 10.1 years of age (average: 5.15 years) and 1–2 unrelated females ranging from 1.5 and 6.5 years of age (average: 4.01 years). Breeding animals under free-roaming management were 1–3 males between 2 and 12.6 years of age (average: 5.73 years) and 1–2 related females (mother and daughter) in the age range 1.5 to 13.52 years of age (average: 6.94 years).

The study analysed daily keeper monitoring records, animal data (Animal Record Keeping System, ARKS) and veterinary records (MedARKS), including clinical notes, bacteriology, parasitology, and pathology reports, of golden-headed lion tamarins managed under traditional husbandry practices (Group A) and captive, free-roaming conditions (Group B). Both hard copies and electronic files were included and compared with daily treatment schedules for accuracy. Preventative medical procedures included standard primate quarantine procedures for acquisitions, individual annual physical examinations with bacteriological faecal cultures for *Salmonella*, *Shigella* and *Campylobacter* spp and parasitological faecal examinations. In addition, annual pooled faecal samples were analysed via bacteriological cultures and sedimentation-flotation parasitological examinations, six months after the individual annual physical examinations.

All statistical analyses were performed using Statistica™ 7.1 (StatSoft® Inc, Tulsa, OK, USA) and significance was set at $P < 0.05$. The categorical variables in the two housing systems were examined using contingency tables. Due to the small sample size either the Mann-Whitney *U* test or the Fisher exact test was used. Survival probability was calculated with an online calculator using the Kaplan-Meier method (Hutchon 2006).

Results

The golden-headed lion tamarins in Group B (captive free-roaming) grew significantly faster than Group A (traditional indoor) (Figure 1). Significantly more animals died in Group A (12/14) in comparison to Group B (11/23) ($P = 0.023$). Probability of survival was higher in Group B for all age groups in comparison to Group A (Figure 2), but due to the low sample sizes, 95% confidence intervals were large. Offspring had a survival probability for the first day of life of 57.1% (22.9–91.4%) in Group A and 86.2% (65.6–99.7%) in Group B. The probability of surviving to reach five years of age was 35.7% (6.3–77.7%) in Group A and 52.2% (23.9–80.4%) in Group B. In contrast, the overall survival probability of the international studbook population was 80.7% (78.8–82.8%) for the first day of life and 34.6% (30.9–38.3%) for the first five years. Birth-related problems were the most frequent causes of death in both study groups. In Group A, three out of five births required medical attention (two caesarean sections in one animal, one stillbirth in another female requiring veterinary attention), in contrast to three stillbirths, requiring no medical help, out of 10 in Group B which, however, required no medical attention ($P = 0.004$). No differences in infectious-, injury-, or alimentary tract-related causes of death (Table 1) were detected between the two husbandry practices ($P > 0.05$). Haemosiderosis was a significant pathological finding in Group A but was considered to be unrelated to the death of three animals. It did not occur in Group B. The number of offspring successfully reaching sexual maturity was significantly greater in Group B (12/20) compared to Group A (1/8) ($P = 0.029$).

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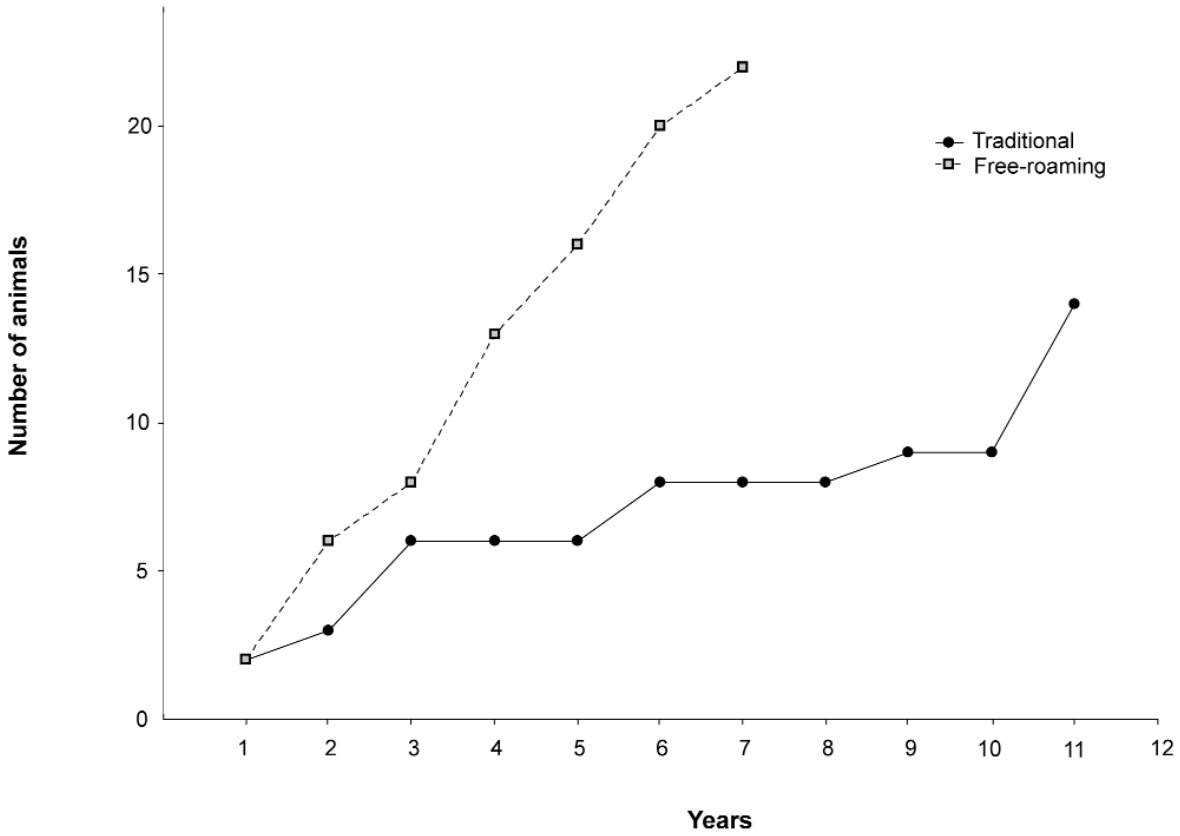
Figure 1



The free-roaming group of golden-headed lion tamarins (*Leontopithecus chrysomelas*) grew from 2 to 22 animals in 7 years, while the group housed under indoor management increased significantly slower from 2 to 14 animals within 10 years.

There were no reports of disease transmission or injury to the public as a result of animal contact throughout the seven-year period of captive, free-roaming conditions. During the first year, the free-roaming population's home range was an area of 10 m diameter around their initial housing. Later, their home range was extended up to 2,500 m^2, but natural borders, eg wide pathways, were accepted so that the animals always remained in the centre of the zoo. One sub-adult male was injured by Siamang gibbons (*Hylobates syndactylus*) while exploring their cage.

Medical problems were diagnosed 17 times in Group A as opposed to seven times in Group B ($P = 0.012$). Overall, bacterial diseases were most common (57%), followed by injuries (19%), dystocia (12%) and parasitic diseases (12%). Bacterial ($P = 0.004$) infections and injuries ($P = 0.022$) occurred significantly more frequently in Group A, while no difference was observed in parasitic diseases (Table 2). Tularaemia (*Francisella tularensis*), a potentially zoonotic disease, was diagnosed in a 2-year old female golden-headed lion tamarin in Group B. The case and diagnostic work-up were published by Hoelzle *et al* (2004) elsewhere. The bi-annual physical examination of Group B revealed no differences in clinical findings at the end of the indoor and outdoor period.

Discussion

This study revealed that captive, free-roaming management (Group B) of golden-headed lion tamarins, as an alternative to indoor husbandry practices (Group A) in a zoo setting, did not significantly compromise welfare or health status. Rather, the present data suggest that captive, free-roaming management practices can have a positive impact, including increased offspring survivability, reduced mortality, less diseases and fewer parturition problems.

Many callitrichid species are successfully housed and bred in small enclosures in research institutions and zoological facilities (Buchanan-Smith *et al* 2004; Prescott & Buchanan-Smith 2004). Many modern zoological institutions use recommended optimum enclosure sizes and environmental conditions for callitrichid groups in mixed-species exhibits (Carroll 2002). The indoor-housed group in this study had space available that was within these housing recommendations. Despite this, these animals were affected significantly more frequently by pathogens than their captive free-roaming conspecifics. It was suspected that captive conditions may have resulted in higher stress levels, as has been shown in other primates (Steinmetz *et al* 2006), leading to depressed immunity. A further indication of stress might be

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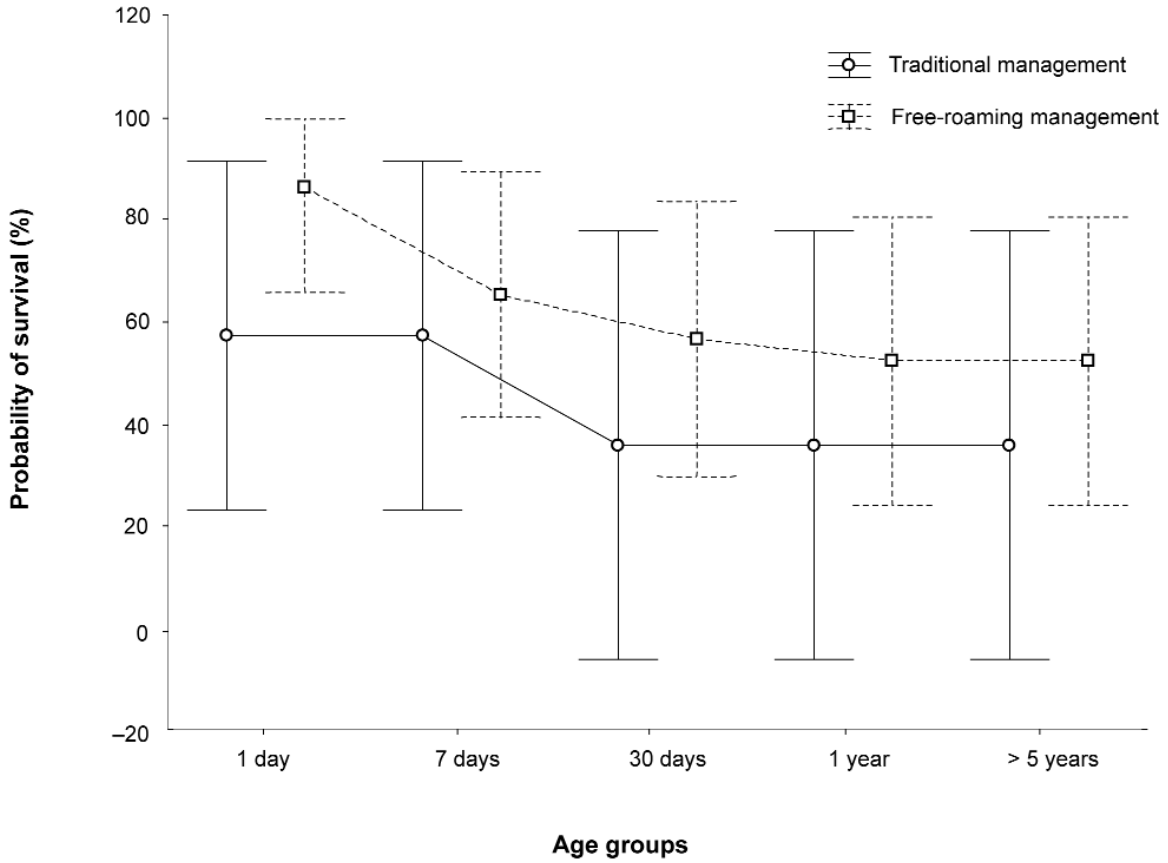
Figure 2



Survival probability calculated after the Kaplan-Meier method (Hutchon 2006) for golden-headed lion tamarins (*Leontopithecus chrysomelas*) housed under traditional and free-roaming conditions.

Table 1 Pathological findings in golden-headed lion tamarins (*Leontopithecus chrysomelas*) housed under indoor (Group A) and captive, free-roaming management (Group B) at Zürich Zoo.

Indoor management	**Captive, free-roaming management**
Group A (n = 15)	**Group B (n = 11)**
Septicaemia (*Escherichia coli*) (n = 1)	Tularaemia (*Francisella tularensis*) (n = 1)
	Meningitis (*Bacteroides* spp) (n = 1)
Dystocia (n = 2)	
Asphyxia (n = 6)	Asphyxia (n = 4)
Injury by cagemates (n = 1)	Injury by predator (n = 1)
Haemosiderosis (n = 3)	Alimentary (n = 2)
Unknown (n = 2)	Unknown (n = 2)

the greater number of bite injuries in the indoor-housed group from cage mates. In contrast, the free-roaming group adapted well to the semi-free conditions and suffered no significant loss to predators. Nevertheless, the case of an injury inflicted by a Siamang gibbon indicates that group size and the exploration of the surrounding area should be monitored carefully; this incidence also indicates the possibility of the spread of disease by free-roaming animals to other animal groups if access to their enclosures is unable to be prevented. Golden-headed lion tamarins' ranging patterns appear to be influenced strongly by resource acquisition (Raboy & Dietz 2004). Finite arboreal living conditions and defined feeding places in the core area made it possible to confine the free-roaming group of golden-headed lion tamarins to a well-defined area in the centre of the zoo. Captive, free-roaming *Callitrichidae* should be housed at a

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Table 2 Diseases diagnosed in golden-headed lion tamarins (*Leontopithecus chrysomelas*) at Zürich Zoo (n Group A/n Group B) during clinical health examinations (fatalities not included).

Bacteria (9/2)	Parasites (4/5)	Non-infectious diseases (6/2)
Campylobacter jejuni (6/0)	Coccidia (2/0)	Bite wound (3/1)
Escherichia coli (1/0)	Toxoplasma (1/2)	Dystocia (3/0)
Salmonella typhimurium (1/0)	Encephalitozoon cunniculi (0/2)	Soft tissue trauma/fracture (0/1)
Bacteroides spp (0/1)	Spiruroidea (1/1)	

safe distance to *Saimiri*, *Cebus*, and *Ateles* spp due to the possibility of *Herpesvirus tamarinus* (*Herpesvirus T*, *Herpesvirus platyrrhinae*) infection, which causes pantropic epizootic infections in callitrichids (Hatt *et al* 2004; Montali & Bush 1999). In addition, visitor-animal contact must be prevented via signs and frequent animal and visitor surveillance through keepers or volunteers to prevent disease transmission, dietary problems or injuries. Although the shedding of pathogens was significantly less frequent in the free-roaming group, zoonotic disease risk cannot be excluded, as the case of tularaemia in the free-roaming group demonstrated. Thus, a regular health programme should be deployed to recognise potential risks at an early stage. This must also take into account the threat posed to the tamarin collection from potential pathogens of human origin, eg *Herpesvirus simplex* or measles (Montali & Bush 1999). One potential way of achieving a relative separation of free-ranging animals from visitors could be the removal of low branches from trees in the animals' home range.

The case of tularaemia suggests that pest control is an important component of captive, free-roaming callitrichid management in zoological settings. Callitrichids are also susceptible to a number of parasites for which cockroaches or rodents serve as intermediate host. Many callitrichid species eagerly forage on cockroaches, further increasing the risk of disease transmission. Therefore, it is emphasised that appropriate cockroach control measures should be practiced on a regular and more frequent basis. Good hygiene and immediate removal of all leftover dietary items is imperative to reduce callitrichid exposure to rodents and other vermin. In conclusion, it would appear that the more natural captive, free-roaming condition resulted in a tendency for a shift from typical crowding-associated (bite wounds, bacterial) disease problems to problems more typical of the wild (trauma-related injuries).

The results of parturition outcomes are remarkable, although the number of investigated animals is low. In contrast to the indoor-housed group, the free-roaming group had no need for medical intervention during labour. It is suspected that increased activity in the captive free-roaming group resulted in a better physical fitness. Investigations into the impact of exercise on labour in women are conflicting (Morris & Johnson 2005). Nevertheless, moderate exercise resulted in a significant increase in maternal (including less labour complications) and foetal health in a number of studies (Clapp 2000; Brown 2002). In the present study, one animal from the indoor-housed group required two caesarean sections, while another had one stillbirth requiring veterinary intervention. Anatomical difficulties in the mother were excluded as the animal gave birth to healthy offspring.

Captive, free-roaming conditions do not automatically imply reduced animal care. Keepers are a key factor regarding disease surveillance, and adequate time must be dedicated to monitoring the animals on a regular basis. Our experiences have demonstrated that injured or sick animals can be identified and easily retrieved in the current free-roaming system. In addition, the necessity for a traditional period indoors throughout winter ensures that regular physical examinations are still possible for the captive, free-roaming group.

This study suggests that the captive, free-roaming management of callitrichid species, such as golden-headed lion tamarins, can be conducive to increased reproductive success, improved health and therefore improved welfare. Current husbandry standards should consider captive free-roaming conditions as a valuable housing practice where health regulations and proper husbandry parameters permit. Nevertheless, further investigations involving additional animals and institutions are recommended due the involvement of only a single institution and a limited number of animals in the present study.

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