EAZA

HUSBANDRY GUIDELINES

FOR

CALLITRICHIDAE

~ 2010 ~

2nd edition

Edited by
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EAZA Husbandry Guidelines for the Callitrichidae

Preamble for the EAZA Husbandry Guidelines

Right from the very beginning it has been the concern of EAZA and the EEPs to encourage and promote the highest possible standards for husbandry of zoo animals. For this reason, quite early on, EAZA developed the "Minimum Standards for the Accommodation and Care of Animals in Zoos and Aquaria". These standards lay down general principles of animal keeping, to which the members of EAZA feel themselves committed. Above and beyond this, some countries have defined regulatory minimum standards for the keeping of individual species regarding the size and furnishings of enclosures etc., which, in the opinion of the authors, should definitely be fulfilled before allowing such animals to be kept within the area of the jurisdiction of those countries. These minimum standards are intended to determine the borderline of acceptable animal welfare. It is not permitted to fall short of these standards. How difficult it is to determine the standards, however, can be seen in the fact that minimum standards vary from country to country.

Above and beyond this, specialists in the EEPs and TAGs have undertaken the considerable task of laying down guidelines for keeping individual animal species. Whilst some aspects of husbandry reported in the guidelines will define minimum standards, in general, these guidelines are not to be understood as minimum requirements; they represent best practice. As such the EAZA/EEP Husbandry Guidelines for keeping animals intend rather to describe the desirable design of enclosures and prerequisites for animal keeping that are, according to the present state of knowledge, considered as being optimal for each species. They intend above all to indicate how enclosures should be designed and what conditions should be fulfilled for the optimal care of individual species.

Introduction

Welcome to this, the Second Edition of the EAZA Husbandry Guidelines for the Callitrichidae. The first edition was published in 2002. The review that has led to this second edition was started in 2008 and completed in 2010.

In some places the changes from the first edition are considerable. This includes a modified structure, to reflect the standard EAZA husbandry guidelines format, introduced in 2008. There has been a considerable revision of Section 1, Biology and Field Data which results from both changes in taxonomy and the discovery of a number of new species over the last decade. Changes in Section 2 reflect advances in husbandry and our greater understanding of diets, health care and social behaviour.

The EAZA Regional Collection Plan for the Callitrichidae highlights the need for sound husbandry and population management in order to maintain our populations of callitrichids in captivity. Some species require considerable management due to small population sizes and difficulties in establishing multiple-generation breeding. Some programmes are vital for conservation reasons, such as those for the pied tamarin and the lion tamarins. Furthermore, our experience over the years tells us that we need constantly to seek advances in the care, wellbeing and welfare of the animals in our breeding programmes. This second edition of the husbandry guidelines has been written by experts in husbandry, taxonomy, social behaviour, nutrition and animal health and reflects what we see as best practice for our animals. We hope it is helpful not only for EAZA zoos, but also

for zoos in other regions. In particular we hope these guidelines are useful for zoos in Latin America, in countries that are fortunate enough to have wild callitrichids. Most primate species are declining in number as their habitat diminishes and zoos have an increasing part to play in helping species in the wild. Best practice husbandry, in all its aspects, is vital to fulfilling that role.

Lastly, if you feel some aspects are not clear, or perhaps missing, or indeed if you have experiences that you feel would be useful to include, please let us know so that we can improve future editions of the guidelines.

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SECTION 1 − BIOLOGY AND FIELD DATA

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Section 1.6 (Diet and Feeding behaviour): Christoph **Schwitzer**[18], Kristin **Leus**[11], Luc **Lorca**[14] and Melissa **Yaxley**[21]

BIOLOGY

1.1 Taxonomy

The taxonomy of the marmosets and tamarins has changed considerably since that proposed by Hershkovitz (1977, 1979, 1982). Hershkovitz recognized two families: Callimiconidae (*Callimico*) and Callitrichidae (*Cebuella*, *Callithrix*, *Saguinus* and *Leontopithecus*), distinguishing them from the remaining platyrrhine genera, which were lumped into the Cebidae. It was the morphological studies of Rosenberger (1980, 1981; see also Rosenberger et al., 1990) that initiated a major change in thinking regarding the higher taxonomy of this group. His thesis involved placing the marmosets, tamarins and *Callimico* in a subfamily (Callitrichinae) in a redefined Cebidae, which otherwise included squirrel monkeys (*Saimiri*) and capuchin monkeys (*Cebus*), the two comprising the Cebinae. This arrangement and slight variations of it were subsequently amply reinforced and justified by numerous genetic studies (for example, Schneider et al., 1993, 1996; Harada et al., 1995; Nagamachi et al., 1996, 1999; Schneider and Rosenberger, 1996). Established platyrrhine classifications today all accept the affinity of *Cebus*, *Saimiri* and the marmosets, tamarins and callimico. Some place them in separate families (Rylands et al., 2000) and others as two subfamilies of the Cebidae (Groves, 1993, 2001, 2005). In this document we place Goeldi's monkey and all the marmosets, tamarins, and lion tamarins in the Family Callitrichidae.

Cronin and Sarich (1978), Seuánez et al. (1989), Pastorini et al. (1998), Chaves et al. (1999), Canavez et al. (1999a, 1999b) and Neusser et al. (2001) have all demonstrated that *Callithrix* (*sensu* Groves, 2001) and *Callimico* are more closely related to each other than *Callithrix* is to *Saguinus* or *Leontopithecus* (for review see Pastorini et al., 1998). Placing *Callimico* in a separate family or subfamily is not valid due to this finding, unless *Saguinus* and *Leontopithecus* are also separated out at the family or subfamily level; see Groves, 2004).

The taxonomy at the level of genera, species and subspecies has also changed since Hershkovitz's synthesis of 1977; he recognized 46 taxa in five genera—*Callimico*, *Cebuella*, *Callithrix*, *Saguinus* and *Leontopithecus*. Eleven new taxa have been described, one of them in a new genus (*Callibella*); one of the saddleback tamarin subspecies recognized by Hershkovitz (1977) has been discounted as a synonym (*acrensis* Carvalho, 1957) (see Peres et al., 1996); we now recognize the validity of three marmosets (*Callithrix kuhlii* Coimbra-Filho, 1985, *Mico emiliae* [Thomas, 1920] and *Cebuella pygmaea niveiventris* Lönnberg, 1940) which Hershkovitz did not; and many of the taxa considered to be subspecies by Hershkovitz (1977) are now considered to be species.

Perhaps the most profound divergence from Hershkovitz's arrangement arises from the conclusion of both morphological and genetic studies that the pygmy marmoset (*Cebuella*) is more closely related to the Amazonian marmosets than the Amazonian marmosets are to the Atlantic forest marmosets (Tagliaro et al., 1997, 2001; Chaves et al. 1999). The same it seems is true for the dwarf marmoset (*Callibella* Van Roosmalen et al., 1998; see Van Roosmalen and Van Roosmalen, 2003). To avoid paraphyly, therefore, there are only two options concerning the generic separation of the marmosets (see Groves, 2004): 1) All belong to one genus (*Callithrix*), a classification adopted by Groves (2001, 2005); or 2) all are placed into distinct genera, with a generic separation of the Amazonian marmosets (the *Argentata* Group of Hershkovitz) on the one hand, and the eastern Brazilian (non-Amazonian) forms (the *Jacchus* Group of Hershkovitz) on the other, as distinct genera. *Mico* Lesson, 1840, is the name available for the Amazonian *Argentata* Group marmosets. This second classification, with the Amazonian marmosets being attributed to the genus *Mico* is followed by Rylands et al. (2000, 2008, 2009; Rylands and Mittermeier, 2008).

Table 1.1.1. Species and subspecies of callitrichids described since 1983.

Callibella humilis (Van Roosmalen, Van Roosmalen, Mittermeier and Fonseca, 1998)	Black-crowned dwarf marmoset
Callithrix kuhlii (Coimbra-Filho, 1985)	Wied's black-tufted-ear marmoset
Mico nigriceps (Ferrari and Lopes, 1992)	Black-headed marmoset
Mico mauesi (Mittermeier, Ayres and Schwarz, 1992)	Maués marmoset
Mico marcai (Alperin, 1993)	Marca's marmoset
Mico saterei (Sousa e Silva Jr and Noronha, 1998)	Sateré marmoset
Mico manicorensis (Van Roosmalen, Van Roosmalen, Mittermeier and Rylands, 2000)	Manicoré marmoset
Mico acariensis (Van Roosmalen, Van Roosmalen, Mittermeier and Rylands, 2000)	Rio Acarí marmoset
Mico rondoni (Ferrari, Sena, Schneider and Silva Jr., 2010)	Rondon's marmoset
Saguinus fuscicollis mura (Röhe, Silva Jr., Sampaio and Rylands, 2009)	Grey-fronted saddle-back tamarin
Leontopithecus caissara (Lorini and Persson, 1990)	Black-faced lion tamarin

We emphasize that the differences between the taxonomies of Groves (2001, 2005) and Rylands et al. (2000, 2008, 2009; Rylands and Mittermeier, 2008) are largely limited to their placement in the family Callitrichidae (Rylands et al.) or the subfamily Callitrichinae (Groves), and to the separation of marmosets into distinct genera (Rylands et al.) as opposed to combining them into one genus but distinguishing the same

species' groups at the subgeneric level (Groves). So, for example, Groves calls the pygmy marmoset *Callithrix (Cebuella) pygmaea*, whereas Rylands et al. refer to it as *Cebuella pygmaea*. Likewise, Groves (2001) calls the silvery marmoset *Callithrix (Mico) argentata*, whereas Rylands et al. refer to it as *Mico argentatus*. Two other differences are 1) Groves (2001) lists the red-cap moustached tamarin as a full species, *Saguinus pileatus*, whereas Rylands et al. follow still Hershkovitz in considering it a subspecies of *S. mystax*; and 2) Groves considers Graells' black-mantle tamarin to be a full species, *Saguinus graellsi*, whereas Rylands et al., like Hershkovitz (1982), list it as a subspecies of *S. nigricollis*. The taxonomies of both Groves (2001, 2005) and Rylands et al. (2000, 2008, 2009; Rylands and Mittermeier, 2008) are otherwise entirely concordant—they recognize the very same diversity of taxa.

Thus, in this document, as in the Regional Collection Plan, we use *Callithrix* for the Atlantic rainforest marmosets (the genus now endemic to Brazil) and *Mico* for the Amazonian marmosets. We also recognize *Callibella* Van Roosmalen and Van Roosmalen, 2003, the dwarf marmoset, as a distinct genus (see Aguiar and Lacher, 2009).

We list 61 species and subspecies of the family Callitrichidae—22 marmosets (*Cebuella*, *Callibella*, *Mico* and *Callithrix*), 34 tamarins (*Saguinus*), four lion tamarins (*Leontopithecus*), and Goeldi's monkey (*Callimico*) (see Rylands et al., 2000, 2006, 2008, 2009; Groves, 2001, 2005; Rylands and Mittermeier, 2008; Röhe et al., 2009). These 61 callitrichids represent some 30% of the extant New World primates.

The Callitrichidae are generally thought to be phyletic dwarfs, i.e. they have evolved from a larger ancestor. During this dwarfing process the marmosets and tamarins have changed from the typical simian primate in several ways. They have acquired claw-like nails, rather than the typical flattened primate nail. They have lost full opposability of the thumb, although the big toe is still fully opposable. All but *Callimico goeldii* have lost the third molar, and all but *Callimico* have multiple births, twins being the rule rather than the exception.

1.2   *Morphology*

The marmosets and tamarins are distinguished primarily by the elongated lower incisors of the marmosets, an adaptation to eating plant exudates (gummivory). The elongated lower incisors are about the same length as the lower canines, which are thus less prominent in the marmosets than the tamarins. The tamarins are accordingly sometimes referred to as long-tusked, while the marmosets are referred to as short-tusked. Marmosets generally have a more complex caecum than the tamarins, probably an adaptation to increased gummivory among the former. Marmosets also have large and visually obvious genitalia that are displayed as part of ritualized threat behaviours.

Callitrichids are small primates, and include the smallest simian, the pygmy marmoset *Cebuella pygmaea*. The adult pygmy marmoset weighs around 120g, while the largest lion tamarins weigh up to 750g. Most adult *Callithrix* weigh around 400–450g, whilst adult *Saguinus* are generally slightly larger at around 450–550g. Morphological adaptations resulting from dwarfism are described above (Section 1.1 Taxonomy).

1.3   *Physiology*

Information on physiology of callitrichids comes from captive studies. As a result of their use as laboratory primates there is a considerable body of literature on their physiology. Relevant aspects of physiology are dealt with in later chapters.

1.4   Longevity

There have been few studies that record deaths of known-age callitrichids in the wild. In captivity callitrichids rarely survive into their 20s, and those that do, usually show signs of infirmity associated with old age (JB Carroll, pers. obs.). However, there is an increasing number of specimens surviving into their 20s and even breeding at that age. We assume longevity in the wild is significantly shorter.

FIELD DATA

1.5   Conservation status/Distribution/Ecology

The Callitrichidae are found only in the neotropical region of South America. The northernmost species, Geoffroy's tamarin (*Saguinus geoffroyi*), extends into southern Panama, but the family is not otherwise found in Central America. They occur in the Caribbean forests of northern Colombia and southern Panama (*Saguinus*), the eastern Andean forests and Amazon basin (*Callimico*, *Callibella*, *Cebuella*, *Mico* and *Saguinus*), the cerrado (tropical savanna) of central Brazil (*Callithrix*), the caatinga (desert scrub and deciduous dry forest) of northeast Brazil (*Callithrix*), the Pantanal and Chaco of Bolivia, Brazil and Paraguay (*Mico*), and the Atlantic rainforest of the east and southeast of Brazil (*Leontopithecus* and *Callithrix*).

They occur in primary or secondary forest, and are most abundant in secondary or disturbed forest. They are arboreal, generally inhabiting the middle and lower storeys of the forest.

1.6   Diet and feeding behaviour

1.6.1   Feeding ecology

In general, the Callitrichidae can perhaps best be described as frugivore–insectivores, feeding on a wide variety of fruits, arthropods and exudates and to a smaller extent buds, flowers, nectar, fungi, snails, small vertebrates (mostly lizards and frogs) and probably also bird eggs and small birds. However the proportion of each of these food items in the diet differs between species, and within species between seasons. Similarly, the way in which the food items are procured differs among species. The callitrichid group as a whole, and within that the different genera and different species, have developed anatomical and behavioural adaptations to make optimum use of those foraging and feeding techniques. After all, each of these monkeys occupies its own feeding niche within its environment (Sussman and Kinzey, 1984; Ford and Davis, 1992; Garber, 1992; Rosenberger, 1992).

Pygmy marmoset *Cebuella pygmaea*

Although there are documented instances of exudate feeding for every genus of the Callitrichidae, *Cebuella pygmaea*, *Callibella humilis* and some members of the genus *Callithrix* are among the most exudativorous of primates (Power, 1996; Power and Oftedal, 1996; Van Roosmalen and Van Roosmalen, 2003). *Callithrix*, *Callibella* and *Cebuella* are the only callitrichid genera with dental adaptations for tree-gouging behaviour: the upper incisors are anchored in a fixed position while the relatively large (almost as long as the canines), chisel-like lower incisors of the cup-shaped anterior lower mandible scoop out the bark (Coimbra-Filho and Mittermeier, 1973; Garber, 1992; Rylands and de Faria, 1993; Power, 1996). They then either lick up the resulting exudate flow or scoop it up with their teeth. None of the other callitrichid genera (*Saguinus*,

Leontopithecus and *Callimico*) have these adaptations for gouging. The latter can therefore only opportunistically feed on exudates, for example at injury sites on trees (as a result of abrasion or wind storms or insect perforations), holes gouged by squirrels or other animals or in the case of *Saguinus fuscicollis* holes gouged by *Cebuella* (Soini, 1987; Snowdon and Soini, 1988).

The pygmy marmoset, *Cebuella pygmaea*, appears to be a true exudate specialist and can be classified as an exudate feeder–insectivore (Soini, 1982, 1988, 1993; Power, 1996). Exudate feeding is a prominent activity of their daily life. On average, 32% of their total daily active time and 67% of their monthly feeding time is devoted to feeding on plant exudates (Ramirez et al., 1977; Soini, 1982). Exudates are furthermore available and consumed all year round. The exudate portion of the diet is mainly complemented by insects and spiders whereas fruits, buds, flowers, nectar and vertebrates form only a minor part of the diet (Soini, 1982, 1988, 1993). Townsend (1999), however, observed a wild-caught pet pygmy marmoset catching and killing a bird. Insects are good sources of protein and lipids but are low in calcium and have low calcium: phosphorus ratios (Oftedal and Allen, 1996; Allen and Oftedal, 1996). They therefore appear to form a good complement for exudates which are high in complex polysaccharides and often contain significant quantities of minerals and especially calcium (Garber, 1992, 1993). (See also Box 1.6.1-1 on exudates and their digestion.)

Marmosets, genera *Callithrix, Callibella* and *Mico*

As indicated above, the marmosets, like *Cebuella*, have the necessary morphological adaptations to gouge holes in trees in order to feed on exudates. There is however quite a bit of variation within the marmosets as far as the importance of exudates in the diet is concerned. The nutritional groupings for the marmoset genera *Callithrix, Callibella* and *Mico* can perhaps best be described as follows (Rylands and de Faria, 1993):

Group 1: Highly exudativorous species: *C. jacchus*, *C. penicillata*

Group 2: Species less exudativorous than group 1 but better adapted for tree gouging than groups 3 and 4: *C. kuhlii*, *C. geoffroyi*

Group 3: Species relatively poorly adapted for tree gouging, the proportion of exudates in the diet depending on availability: *C. aurita*, *C. flaviceps*

Group 4: Highly frugivorous species, relatively poorly adapted for tree gouging and only seasonally exudativorous: e.g. *M. humeralifer*, *M. argentatus*

For the animals of Group 1, which are expertly adapted for both acquiring and digesting exudates whenever the need arises (see Box 1.6.1-1), exudates form an important substitute for fruits at times and places when these are rare. Because this ensures the animals a regular supply of carbohydrates and some minerals (such as calcium) all year round, they can live in small home ranges in forest patches with highly seasonal availability of fruits and insects (disturbed forests and/or dry, harsh climates) (Stevenson and Rylands, 1988; Caton et al., 1996). Extrapolating from this, it can be hypothesised that the marmosets of the lusher and wetter Atlantic coastal forest (*C. kuhlii*, *C. aurita*, *C. flaviceps* and *C. geoffroyi*) depend less on exudates than *C. jacchus* and *C. penicillata*, but probably more so than the Amazonian marmosets (Stevenson and Rylands, 1988).

For Groups 2–4, exudate feeding is to a greater or lesser extent seasonal and mostly negatively correlated to the availability of fruit (Rylands and de Faria, 1993). These marmosets can perhaps be better described as frugivore–insectivores.

All marmoset species spend a considerable part of their day foraging for animal prey (24–30% of their daily activity, Stevenson and Rylands, 1988). Animal prey mostly consists of insects and spiders and, to a lesser extent snails, frogs, lizards, small birds and bird eggs. (See also Box 1.6.1-1 on exudates and their digestion.)

Tamarins, genus *Saguinus*

The bulk of the diet in all the tamarin species studied consists of insects and fruits (Snowdon and Soini, 1988). Tamarins in general can therefore be regarded as insectivore–frugivores.

They complement their diet with smaller (or seasonal) amounts of exudates (gum and/or sap), nectar, snails, honey, flowers, leaves, buds, fungi, bark and small vertebrates. The relative proportions of the different food items depend on the availability. Tamarins tend to maintain a considerable intake of invertebrates, mostly orthoptheran insects, throughout the year (30–77% of total feeding and foraging time) (Terborgh, 1983; Soini, 1987; Garber, 1993).

Fruits form the most important plant food source for most of the year (ripe fruits account for 20–65% of total feeding time) (Snowdon and Soini, 1988; Garber, 1993), but what happens during peak fruiting seasons or periods of fruit scarcity depends on the species and the location. For example, the diet of the golden-handed tamarin *Saguinus midas* in French Guiana contained, on an annual basis, 47.1% fruit and 50.2% invertebrates, making it the most insectivorous species so far studied in French Guiana. Even during peak fruiting season this species did not increase its intake of fruit but took advantage of the concurrent greater insect availability and increased its insect intake, possibly as a result of competition with larger sympatric primates (Pack, 1999). Terborgh (1983) studied emperor tamarins *Saguinus imperator* and saddle-back tamarins *Saguinus fuscicollis* at Cocha Cashu in Peru and found that *S. imperator* spent 34% of the daily time budget on insect feeding and 16% on plant material feeding. For *S. fuscicollis* this was 16% and 16% respectively (they spent a lot more time resting than *S. imperator*). During the wet season both species spent more than 95% of the total plant feeding time feeding on fruits. During the dry season *S. imperator* only spent 41% of the plant feeding time on fruits but spent 52% feeding on nectar. Plant feeding time spent feeding on fruits for *S. fuscicollis* during the dry season dropped to 16% to the advantage of feeding on nectar (75%). Garber (1988b), studying *S. mystax* and *S. fuscicollis* in northeastern Peru, also found that for these species, nectar rather than exudates was the main replacer of fruit during the dry season months (22–37% of foraging and feeding time). In contrast, the *S. fuscicollis* studied by Soini (1987) at a different site in northeastern Peru switched largely to exudate feeding rather than nectar feeding during the dry season. Although fruit was quantitatively the most important plant food resource during the wet season, during the peak dry season 58% of plant feeding time was spent consuming exudates (compared to 4% during the wet season) (Soini, 1987). 45% of daily activities consisted of insect foraging and 14% feeding on plant resources.

As mentioned above (see also Box 1.6.1-1), tamarins do not have the anatomical adaptations for tree gouging and for digesting large amounts of gum. They do feed on gums and sap opportunistically (at tree injury sites or holes gouged by other animals) but in most species exudate feeding is only a seasonal phenomenon and accounts for less than 5% of the total feeding time (Garber, 1993; Power, 1996; Power and Oftedal, 1996). Saddle-back tamarins appear to form an exception to this in that they consume gums more consistently throughout the year and at higher levels than other species (12% of monthly feeding time with a range of 5–58%) (Terborgh, 1983; Soini, 1987; Garber, 1988a; Power, 1996). Because captive tamarins did improve their ability to digest gum the longer they received it (although never reaching the efficiency of the marmosets) it is possible that the more constant ingestion of gum by the saddle-back tamarin enables it to maintain a higher digestibility of this product than other tamarins. Saddle-back tamarins are also highly

insectivorous and it is therefore possible that for them, gums serve primarily as a mineral (calcium) source rather than an energy source (Power, 1996).

Lion tamarins, genus *Leontopithecus*

The lion tamarins can be classified as frugivore–insectivores, with fruits (preferably soft, sweet and pulpy fruits) and insects making up the bulk of their diet, complemented by smaller amounts of other invertebrates, flowers, exudates, nectar, fungus and small vertebrates such as frogs, small lizards and snakes and nestling birds (Coimbra-Filho and Mittermeier, 1973; Kleiman et al., 1988; Rylands, 1993; Dietz et al., 1997). Unique for the lion tamarins is that much of the foraging for prey takes place in epiphytes, particularly epiphytic bromeliads (see section: foraging behaviour). For example, of its total daily activity budget, *L. chrysomelas* spent 24% feeding on plant foods, 13% foraging for animal prey and 3% feeding on animal prey whereby nearly half of the animal prey foraging took place in bromeliads (Rylands, 1989). Lion tamarins have also been observed to eat the leaf bases and flower petal bases of small bromeliads (Lorini and Persson, 1994; Prado, pers. comm.).

During the dry season, when fruit is rare, golden lion tamarins *L. rosalia*, golden-headed lion tamarins *L. chrysomelas* and black lion tamarins *L. chrysopygus* have all been observed to eat nectar and a small but significant amount of exudates (Peres, 1989; Rylands, 1993; Dietz et al., 1997). Exudate feeding has so far not been observed for the black-faced lion tamarin *L. caissara*, but this may be due to the fact that most observations were made during the rainy season when fruit was plentiful (Valladares-Padua and Prado, 1996). Like the tamarins, lion tamarins lack morphological adaptations for tree gouging and tend to be opportunistic exudate feeders (Peres, 1989; Rylands, 1989, 1993). However, *L. rosalia* has also been observed eliciting exudate flow by actively biting the base of certain lianas (Peres, 1989).

Goeldi's monkey *Callimico goeldii*

Comparatively little is known about the feeding habits of *Callimico* in the wild (Pook and Pook, 1981; Heltne et al., 1981). *Callimico* appears to be mainly frugivorous. During the wet season they exhibit a preference for soft, sweet fruits. From the invertebrate fraction, mainly insects and spiders are consumed. Occasionally the animals also feed on buds, young leaves, fruit of low epiphytes, ants, etc. During the dry season, when fruits become scarcer, gum from the pods of *Piptadenia* and *Parkia velutina* is consumed (Pook and Pook, 1981; Porter et al., 2009). Interestingly, *Callimico* have been observed to consume fungi at a higher rate than any other primate, especially during the dry season (Hanson, et al., 2003; Hanson, et al., 2006; Porter et al., 2009). The sporocarps that are consumed by this monkey have been found to comprise primarily structural carbohydrates, with a small amount of simple sugars and fat that would provide some energy to the animals (Hanson, et al., 2006).

Marmosets, as an adaptation to exudativory, have reduced small intestines and enlarged compartmentalized caecums, which allow for hindgut fermentation of the structural carbohydrates in gums (Lambert, 1998). Hanson et al. (2006) suggest that because *Callimico* are phylogenetically close to marmosets, they would have a similar gut morphology, allowing for the digestion of fungi. In their nine-month field study on one group of *Callimico* in northern Bolivia, Porter et al. (2009) found the animals to exploit fungi during 42±9% of feeding observations. Ripe fruits accounted for 27±5%, arthropods for 14±2%, pod exudates for 12±3%, and trunk and stilt root exudates for 1±0% of feeding observations. Whereas feeding time on arthropods remained relatively constant throughout the year, the use of other food items varied (Porter et al., 2009). The authors propose that *Callimico* use exudates as fallback foods during times of fruit scarcity.

1.6.2   Foraging behaviour

Gums

Exudate feeding trees are often visited repeatedly for extended periods of time (Stevenson and Rylands, 1988). Exudate holes are also often scent marked. In the case of *Cebuella pygmaea*, a group usually has one principal exudate source tree for the dominant couple and the youngest offspring (Soini, 1982). The older offspring often have a more restricted access to this tree and for them the secondary source trees of the dominant couple and young offspring form the principal exudate sources.

For *Cebuella pygmaea*, *Callithrix jacchus* and *C. penicillata*, and to a lesser extent the other marmosets, gum is an essential part of their diet in the wild (particularly at times when other food items are scarce) and exudate feeding and tree gouging occupies a large proportion of their daily activities. *Cebuella pygmaea* and *Callithrix* species are able to truly gouge trees (see above). For the other callitrichid species exudates are of a limited and more seasonal importance. Some tamarins have been observed to extract gum from crevices by sticking a hand into the source and licking the exudate from the fingers (Snowdon and Soini, 1988). When feeding on the gum of the pods of the *Piptadenia* tree, *Callimico* was observed to hang upside down by its hind feet from the branch that the stem was attached to. They then either reach the seed pods or pull them up by means of the flexible stem (Pook and Pook, 1981). Heymann (1999) observed *S. mystax* in the wild and found that most of the gum feeding took place in the afternoon.

Box 1.6.2-1: Exudates and gum digestion

There are four main types of exudates which are each structurally, chemically and nutritionally distinct from one another (Stevenson and Rylands, 1988; Lambert, 1998):

- <u>Resins:</u> Produced in resin ducts by conifers and some tropical angiosperms. Derivatives of the plant metabolites phenols and terpenes. Insoluble in water. Not known to be consumed by any primate species.
- <u>Gums:</u> Have a water-soluble fraction and are high in complex carbohydrates composed of non-starch, multibranched polysaccharides. Gums contain no fat and no vitamins but some gums have a small protein fraction (0.5%-35% by weight) and they often contain significant quantities of nutritionally important minerals such as calcium, magnesium and potassium (Garber, 1993). Many families of tropical angiosperms produce gums. Gums coagulate to form a gelatinous or solid mass. Readily consumed by Callitrichidae and some other primates.
- <u>Saps:</u> Exudates of xylem and phloem (all trees therefore produce sap). Water-soluble and high in simple, relatively easy to digest, carbohydrates.
- <u>Latex:</u> Similar to gum but milky white, yellow or red. Contain terpenes, tannins and resinous elements as well as small amounts of proteins and non-reducing sugars. Rarely consumed by primates. Latex turns rubbery or solid on exposure to air.

During gouging for gum or as a result of injury to a tree, gum often gets mixed with sap. All Callitrichidae, to a greater or lesser extent, therefore consume gums and saps. Only marmosets will exceptionally feed on latex (Stevenson and Rylands, 1988; Garber, 1993).

Gums are multi-branched, β-linked polysaccharides and are resistant to mammalian digestive enzymes. This means that microbial fermentation is required in order for the animal to access the energy from these carbohydrates (Power, 1996; Power and Oftedal, 1996; Caton et al., 1996). The same appears to be true of their mineral content (Power, 1996). It can therefore be hypothesised that gum feeders have anatomical and physiological adaptations that help to increase the digesta residence time within those regions of the gut where fermentation occurs (Ferrari and Martins, 1992; Power and Oftedal, 1996). Indeed, the caecum and colon represent a larger portion of the gastro-intestinal tract in marmosets than in other callitrichids (Ferrari and Martins, 1992; Power, 1996). The blunt ended and U-shaped marmoset caecum is of equal calibre to the colon and shows sacculations (Ferrari and Martins, 1992; Caton et al., 1996).

Because gums have a water-soluble fraction they can be expected to travel with the liquid components of the digesta. Transit time studies carried out on *C. jacchus* by Caton et al. (1996) showed that in this species, fluid digesta are selectively retained in the large caecum. The study therefore suggests that the common marmoset employs a two-part digestive strategy (Caton et al., 1996):

1) Rapid digestion in the stomach and the long small intestine of high-quality foods such as fruits and insects for immediate energy requirements for daily activities.
2) Selective retention and fermentation in the caecum of the soluble complex polysaccharides from the exudates as well as very small particles from insect exoskeletons. Exoskeletons are primarily made of chitin, a stiff polysaccharide that can be broken down by microbial fermentation (Lambert, 1998). This fermentation in the caecum provides a slower but constant background production of energy.

A comparative digestibility and transit time study (Power, 1996; Power and Oftedal, 1996) on *Cebuella pygmaea*, *Callithrix jacchus*, *Saguinus fuscicollis*, *Saguinus oedipus* and *Leontopithecus rosalia* revealed that when fed a diet that contained gum arabicum, the transit time of the marmosets tended to increase (although not statistically significant) while their digestive efficiency remained unaffected. In the tamarins and the golden lion tamarin the transit time was unaffected by the gum but their digestive efficiency was reduced, confirming that tamarins and lion tamarins are anatomically and physiologically less well adapted to the ingestion and digestion of gums.

Animal prey

Animal prey foraging patterns of callitrichids can be broadly classified into at least three different categories (adapted from classification for *Saguinus* from Garber (1993)).

Pattern 1: Energetic foraging on thin, flexible branches.
Animals energetically climb, grasp and jump on thin flexible branches of low shrubs and vine tangles (0–5 m above the ground). Prey is caught by rapidly striking forelimbs, while hindlimbs maintain a firm grasp on the supporting vegetation (e.g. *Saguinus geoffroyi*).

Pattern 2: Stealthy stalk and pounce technique, or "leaf gleaning" technique.
Locomotion involves bouts of stealthy walking while continuously alert on the immediate surroundings. Animals creep along branches in the understorey and middle layers of the forest, often placing the head close to the branch and foliage while motionlessly looking along the branches and leaves, probably for profiles of camouflaged insects. Capture involves stalking, pouncing and trapping prey (for example between two cupped hands). Hunt on exposed, visible (but often camouflaged) prey capable of rapid escape (e.g. *Cebuella pygmaea*, *Callithrix* spp., *Mico* spp., *Saguinus mystax*, *Saguinus labiatus*, *Saguinus imperator*, possibly *Saguinus midas*). Animals from this category occasionally also forage by manipulation (pattern 3).

Pattern 3: Manipulative specific site foraging.
This pattern is typified by cling-and-leap locomotion and vertical clinging postures on moderate to large supports, such as trunks and large branches. From a stable position, specific microhabitats such as knotholes, crevices, cracks, bark and other regions of the trunk are explored. For lion tamarins specifically, the most important microhabitat foraging sites are epiphytes and especially epiphytic bromeliads. The animals feed largely on non-mobile, hidden prey, a considerable proportion of which is located by touch rather than sight. The long, slender hands and fingers of the lion tamarins are excellently suited for this type of foraging (e.g. *S. fuscicollis* (possibly also *S. nigricollis* and *S. bicolor*), *Leontopithecus* sp.).

Little is known about the foraging habits of *Callimico* in the wild, and it is not yet clear to which, if any, of the above insect foraging patterns the species belongs. Animals have repeatedly been seen to jump down to the ground and immediately jump back up again, holding a large grasshopper in the mouth (Pook and Pook, 1981). Their cling-and-leap locomotion style at a preferred height of 2–3m above the ground may help with this prey catching technique.

Fruit

The methods for foraging for fruits are quite similar among the callitrichids (Rylands, 1981; Snowdon and Soini, 1988; Stevenson and Rylands, 1988). Most of the fruits eaten are small and are pulled or bitten off the tree and are then held in both hands while they are eaten. Larger fruits are eaten while still attached to the tree. *C. jacchus* was observed hanging upside-down from the hind legs to feed on dangling fruit (Stevenson and Rylands, 1988). With fruits larger than the animal, they cling to the outer surface of the fruit and gouge holes to the interior.

For most callitrichids, the indigestible bulk of the diet largely consists of seeds that are swallowed whole and are passed through the digestive tract largely unchanged (Heymann, 1992; Power, 1996; Dietz et al., 1997). Callitrichids therefore appear to play a role as seed dispersers in the tropical forest (e.g., Passos, 1997).

Table 1.6.2-1: Overview of callitrichid feeding ecology (Table from NRC, 2003; for references see there © National Academy of Sciences)

Scientific Name		Diet[a]	Behavior	Body Weight[b]	References
Fruit and insect foraging dominate diet, gums seasonally important					
Callithrix					
C. argentata	Bare-ear marmoset	27% (24-30%) of total daily activity foraging for insects; therefore, total feeding time spent on insect foraging 56% (50-63%), fruit 33% (28-37%), exudates (gums) 11% (5-16%); when fruit scarce, exudate intake increased	Diurnal, arboreal mostly, multimale/ multifemale group size 3-20 individuals	190-320 g females, 357-450 g males; C. nigriceps 370 g male, 390 g female	Ferrari, 1993; Ferrari & Ferrari, 1989; Ferrari & Rylands,1994; Ford & Davis, 1992; Harrison & Tardif, 1994; Koenig, 1995; Muskin, 1984; Rylands, 1993; Rylands & de Faria, 1993; Stevenson & Rylands, 1988
C. aurita	Buffy tufted-eared marmoset				
C. geoffroyi	Geoffroy's tufted-eared marmoset				
C. humeralifer	Tassel-eared marmoset				
C. kuhlii	Wied's tufted-eared marmoset				
C. mauesi[c]	Maues marmoset				
C. nigriceps	Black-headed marmoset				
Fruit dominates, insects important, gums or nectar seasonal					
Leontopithecus					
L. caissara[c]	Black-faced lion tamarin	Ripe fruit 53% (32-78%), insect foraging 25% (14-50%) of feeding time, unripe fruit 6-7%, exudates (gums) 9% (1-20%), nectar 7% (0-43%)	Diurnal, arboreal mostly, pairs or multimale/ multifemale 2-3 adults/group, 2-16 total	361-794 g females, 437-710 g males	Albernaz, 1997; Butynski, 1982; Dietz et al., 1997; Ferrari, 1993; Ferrari & Ferrari, 1989; Ford & Davis, 1992; Rylands, 1993; Tardif et al., 1993
L. chrysomelas	Golden-headed lion tamarin				
L. chrysopygus	Black lion tamarin				
L. rosalia	Golden lion tamarin				
Gums dominate, insects important, fruit can depend on location					
Callithrix					
C. jacchus	Common marmoset	Exudates (gums) 45% (24-70%), fruit 16% (14-30%), insect foraging 39% (30-70%), nectar in dry season; C.pygmaea exudates (gums) 60% (30-77%), fruit 8% (0-10%), insects 30% (20-33%)	Diurnal, arboreal mostly, multimale/ multifemale, groups 1-15; C. pygmaea monogamous families, up to 4 litters living together	182-354 g females, 225-406 g males; C. pygmaea 112-140 g females, 99-160 g males	Coimbra-Filho & Mittermeir, 1978; Ferrari & Ferrari, 1989; Ferrari & Rylands, 1994; Ford & Davis, 1992; Ramirez, 1985a; Rylands & de Faria, 1993; Silva & Downing, 1995; Soini, 1982, 1988, 1993
C. flaviceps	Buffy-headed marmoset				
C. penicillata	Black tufted-eared marmoset				
C. pygmaea (was genus Cebuella)	Pygmy marmoset				
Insects and fruit dominate, gums and nectar seasonally important					
Callimico					
C. goeldii	Goeldi's monkey	Preferred food insects; also soft, sweet fruit in wet season, sticky coating of gum on pods in dry season; rarely buds or young leaves; diet similar to Saguinus spp, sometimes live with mixed Saguinus troops	Diurnal, arboreal mostly, monogamous pairs, some within group, 2-8 individuals	400-535 g	Ford & Davis, 1992; Heltne et al., 1981; Mittermeier & Coimbra-Filho, 1977; Pook & Pook, 1981, 1982
Saguinus					
S. bicolor	Bare-faced tamarin	Insects 45% (30-77%), fruit 35% (13-74%), exudate 10% (0-37%), nectar 7% (0-35%), young leaves 3%, seeds; 34.8% of total activities foraging for insects, 17% plant foods; insect capture rate might be only 5.4% of prey-foraging time	Diurnal, arboreal, multimale/ multifemale groups, 2-16 individuals; S. imperator, S. labiatus, and S. midas multimale/ multifemale, but only 1 reproducing female	272-600 g females, 242-633 g males	Crandlemire-Sacco, 1988; Egler, 1992; Ferrari & Ferrari, 1989; Ford & Davis, 1992; Garber, 1984, 1988, 1993a,b; Harrison & Tardif, 1994; Lopes & Ferrari, 1994; Pack et al., 1999; Peres, 1993a; Ramirez, 1985a,b; Skinner, 1985; Silva & Downing, 1995; Soini, 1987; Terborgh, 1983
S. fuscicollis	Saddleback tamarin				
S. geoffroyi	Red-crested tamarin				
S. imperator	Emperor tamarin				
S. inustus[c]	Mottled-faced tamarin				
S. labiatus	Red-bellied tamarin				
S. leucopus	Silvery-brown bare-faced tamarin				
S. midas	Golden-handed tamarin				
S. mystax	Mustached tamarin				
S. nigricollis	Spix's black-mantled tamarin				
S. cedipus	Cotton-top tamarin				
S. tripartitus[c]	Golden-mantled saddleback tamarin				

[a] Diet format: mean (range).
[b] Body weights in ranges whenever possible; single numbers are not averages but indicate that only one individual of the species has been weighed in the wild.
[c] No data available from the wild but assumed to be similar to congenerics.

1.7   Reproduction

The Callitrichidae were once thought to be monogamous and most callitrichid social groups have only a single breeding female. Many field studies, however, have noted multiple breeding males and, less frequently, more than one breeding female. In captivity at least breeding by subordinate females in most groups of most species is apparently suppressed physiologically. Subordinate females do not show oestrous cycles. The

exception to this is the lion tamarins, in which subordinate females do exhibit ovulatory cycles. It is thought that suppression of breeding in these species is by behavioural means.

With the exception of *Callimico* all Callitrichidae typically have twin births. Singleton and triplet births are not, however, unusual. Quadruplet births occur rarely. In *Callimico*, twin births are exceptionally rare in captivity, while triplets and quadruplets have never been recorded.

All callitrichids show shared infant care, with all members of the group participating in carrying and grooming the infants. Sometimes the mother may only have the infants in order to feed them. All group members will usually share solid food with a weaning infant. Further information is given in Sections 2.3 and 2.4.

1.8   Behaviour

Callitrichidae all live in social groups, within which a dominance hierarchy may, but not always, be evident. The composition of groups is highly variable, but usually contain several adults of both sexes. Most contain a single breeding female. This female may cohabit with several breeding males, and the group may also comprise offspring of various ages, some of adult age. Rarely, groups have been seen with more than one breeding female in the wild. Such groups are rarely stable over the long term in captivity.

Callitrichids show the typical range of primate social behaviours. In captivity, aggression between family group members is rare. A wide range of vocalisations is apparent. Facial expressions are more limited, but are nevertheless seen. Scent marking is a common means of communication.

There are three scent gland fields, the sternal, suprapubic and circumgenital. The appearance of the scent gland varies with gender and species. How much each scent gland field is used also varies with species and gender. It is thought that information such as identity, age and sexual condition can be conveyed through scent marks. Scent marks also have a territorial function, and territory boundaries are marked frequently.

The Callitrichidae are arboreal and travel is usually by quadrupedal locomotion. Some species will use vertical clinging and leaping to travel between vertical perches, while they will also sometimes go to the ground to travel from tree to tree.

They are diurnal, emerging from sleeping sites shortly after dawn and usually retreating to sleeping sites in the late afternoon before the sun begins to set. Group members usually sleep in contact or close proximity in a tree cavity or vine tangle.

Some species form associations with other species and will travel or forage in mixed groups, and defend a common territory.

SPECIES ACCOUNTS

Species are listed below alphabetically within genera by specific name. Conservation status classification follows the *IUCN Red List of Threatened Species* (IUCN, 2009).

Callibella humilis (Van Roosmalen, Van Roosmalen, Fonseca and Mittermeier, 1998)

Common name:
Black-crowned dwarf marmoset

IUCN IUCN Red List: Vulnerable (VU)
CITES: Appendix 2
Regional Collection Plan: DO NOT OBTAIN

Taxonomy:
This marmoset was discovered and described in 1998. It was first described in the genus *Callithrix*. Van Roosmalen and Van Roosmalen (2003) placed it in its own genus, *Callibella*. Genetically this marmoset is basal to all Amazonian clades and its cranial morphology is distinct from all other marmosets (Aguiar and Lacher, 2003; Van Roosmalen and Van Roosmalen, 2003).

Habitat & Distribution:
Callibella humilis lives in secondary forest, south of the Rio Madeira, along the west bank of the Rio Aripuanã. The rios Mariepauá and Arauá may form the southern limit to its range, but its extent is not known. It is sympatric with the larger *Mico manicorensis*.

Morphology:
At 150–185 g and head-body length 160–170 mm, *Callibella humilis* is larger than the pygmy marmoset *Cebuella*. It is dark olive-brown above, orange-yellow to golden to greyish-yellow on the ventral surface, and easily distinguished from *Callithrix* on the basis of size.

Reproduction:
There is no information available regarding its life history.

Diet:
Assumed to be fruit, exudates, animal prey and insects. It spends a lot of time gouging bark on tree trunks.

Behaviour:
Poorly known at present, but it often assumes an upright squirrel-like posture on vertical trunks.
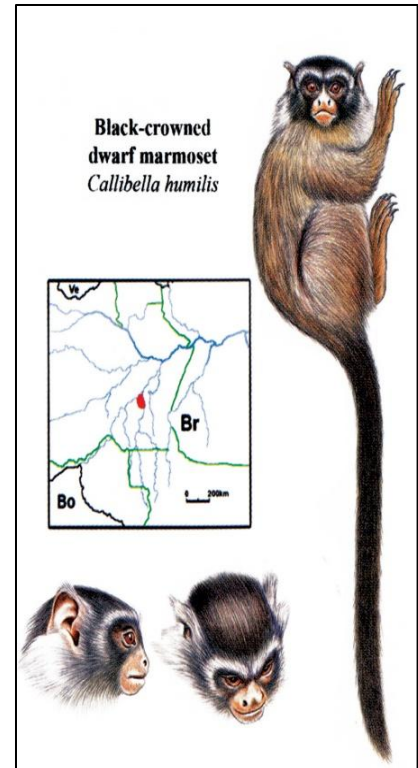
Callimico goeldii (Thomas, 1904)

Common names:
Goeldi's monkey, Callimico

IUCN Red List: Vulnerable (VU)
CITES: Appendix 1
Regional Collection Plan: EEP

Taxonomy:
To date, *Callimico* is a monotypic genus, although speculation persists regarding the possibility of there being more than one species or subspecies. Vàsàrhelyi (2002) examined the genetic structure of the founder stock of captive callimicos and concluded that more than one cryptic subspecies or species may be represented.

Habitat & Distribution:
Goeldi's monkeys live in tropical mixed-level rain forest with undergrowth and bamboo. Their habitat extends throughout the western Amazon basin, in Brazil, Bolivia, Peru and Colombia. It has never been recorded from Ecuador.

Morphology:
This species grows up to an average of 222 mm and the tail length ranges from 255 to 324 mm. They weigh between 400 and 535 g. The fur is black, sometimes tipped with grey or brown. The hair is long and sticks out, sometimes resulting in a "dishevelled" appearance. The anterior crown of the head has characteristic upright hair. They have a clearly defined and visually obvious sternal scent gland. Adults have 36 teeth, having retained M_3, which has been lost in the other Callitrichidae.

Reproduction:
Goeldi's monkeys have variable social structures in the wild. They vary from monogamous pairs to multimale/multifemale groups with one breeding pair and sometimes more than one breeding female. Weaning of infants occurs at around 65 days. Both sexes typically reach maturity at about 13 months, although one female has been reported as conceiving at 8.5 months of age. Oestrous cycle duration is 24 days and gestation takes about 154 days (range 144–165). Females may give birth to their first offspring at about 16 months of age. A post-partum oestrus usually occurs at 5 to 10 days. Unlike all other Callitrichidae a single infant is the norm, and the infant care pattern is different to that typically seen in callitrichids. The female carries the offspring for about the first three weeks. The male and other group members then share the carrying until the infant is independent. From about day 42, infants start to travel independently.

Diet:
Goeldi's monkeys feed on fruit and animal prey. Fungi are also now known to be an important food source. They prefer to forage below 5 m but they also feed at the top of tall trees when they are in fruit.

Behaviour:
Group cohesion is very strong and group size varies between 2 and 8 individuals. They are diurnal and arboreal, preferring to travel below 5 m. Most locomotion is quadrupedal although vertical clinging and leaping has been observed up to 4 m. They use tangles below 15 m as sleeping sites. Goeldi's monkeys scent mark their tails by coiling the tail between the hind limbs and rubbing it against the genitals and the sternal scent gland. They have seven different types of vocalization, including a shrill long-distance call. Tamarins (*Saguinus*) often answer their calls.
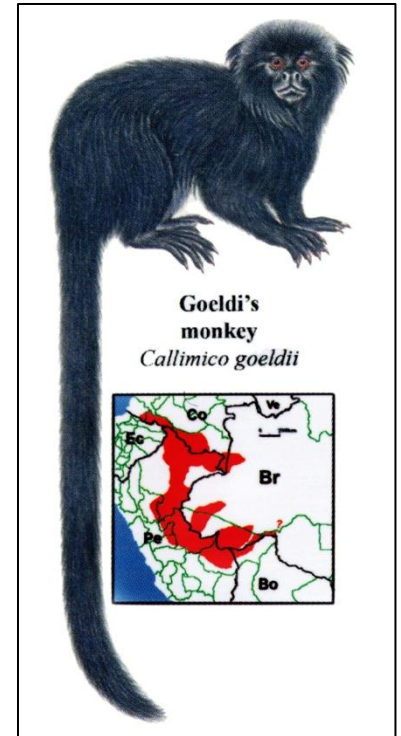
Callithrix aurita (É. Geoffroy, 1812)

Common name :
Buffy tufted-eared marmoset

IUCN Red List: Vulnerable (VU)
CITES: Appendix 1
Regional Collection Plan: DO NOT OBTAIN

Taxonomy:
Previously considered a subspecies of *Callithrix jacchus* (see Hershkovitz, 1977).

Habitat & Distribution:
Callithrix aurita lives in upland evergreen and semi-deciduous forest above 400–500 m, in montane forests in southern Minas Gerais, Rio de Janeiro, and east and northeast São Paulo in south-east Brazil.

Morphology:
Buffy tufted-eared marmosets have black body fur with rufous speckling, a white blaze on the forehead, a rufous crown and yellowish ear tufts. They weigh around 400 to 450 g.

Reproduction:
There is no information available regarding life history in the wild.

Diet:
Callithrix aurita feeds on fruit, animal prey, exudates and fungus.

Behaviour:
Little is known about their social structure. Unlike other marmosets, this species has lower incisors poorly adapted for gouging trees to produce sap. As a result, exudate eating is usually confined to flow from damage caused by wood-boring insects. It is also reported that they use their lower front teeth to remove tree bark and eat termites and wood-boring insects.
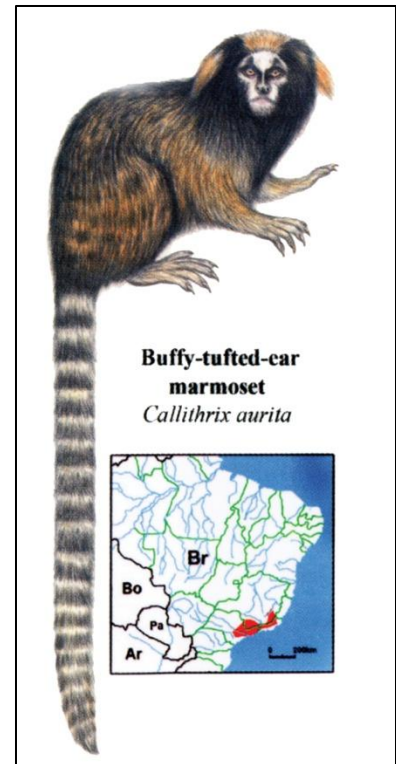
Callithrix flaviceps (Thomas, 1903)

Common name:
Buffy-headed marmoset

IUCN Red List: Endangered (EN)
CITES: Appendix 1
Regional Collection Plan: DO NOT OBTAIN

Taxonomy:
Previously considered a subspecies of *Callithrix jacchus* (see Hershkovitz, 1977).

Habitat & Distribution:
Buffy-headed marmosets live in highland evergreen and semi-deciduous forest above 400 m in the Serra da Mantiqueira in southern Espírito Santo, south of the Rio Doce to the state boundary with Rio de Janeiro, west into eastern Minas Gerais in the Rio Manhuaçu basin in southeast Brazil.

Morphology:
These animals are called buffy-headed because of the yellowish buff-coloured head and short yellow ear tufts. They grow up to an average of 231 mm with 322 mm of tail length and weigh around 406 g.

Reproduction:
Very little is known about this species regarding their life history, except that females may breed with a 6 month interval.

Diet:
Callithrix flaviceps feeds on gums, animal prey, fruits and seeds.

Behaviour:
Group size is around 9 individuals, varying between 5 and 15.
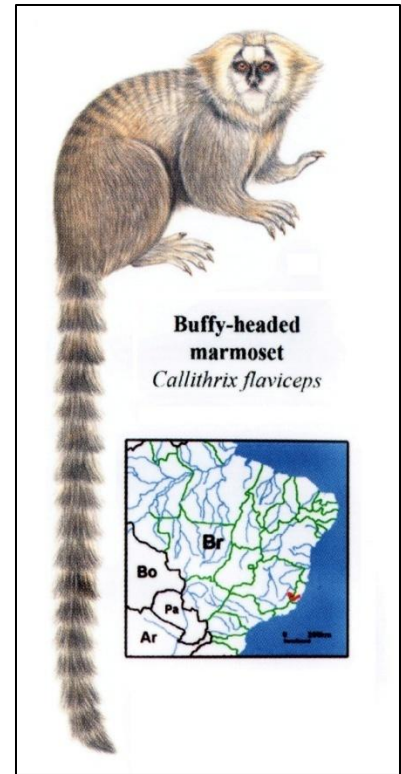
Callithrix geoffroyi (Humboldt, 1812)

Common names**:**
Geoffroy's marmoset
White-faced marmoset
White-fronted marmoset

IUCN Red List: Least Concern (LC)
CITES: Appendix 2
Regional Collection Plan: EEP

Taxonomy:
Previously considered a subspecies of *Callithrix jacchus* (see Hershkovitz, 1977).

Habitat & Distribution:
They live in secondary lowland, evergreen and semi-deciduous forest and forest edge up to 500 m. Disturbed forest is preferred over mature forest.
They occur in Espírito Santo and east and northeast Minas Gerais, south and east of the rios Jequitinhonha and Araçuaí in east Brazil.

Morphology:
Geoffroy's marmosets have a white face and forehead extending back over the crown. The ears have black tufts. The body is blackish/brown with distinctive brindled pattern with dark brown underparts. The tail is ringed.
An adult measures around 198 mm with a tail length of 290 mm, and weighs up to 350 g.

Reproduction:
There is little information available on this species' life history. The male coils his tail as a sexual display during copulation.

Behaviour:
Geoffroy's marmosets have been observed following army ant swarms to catch insects flushed from hiding by the ants. These marmosets occasionally feed with *Callicebus personatus*.
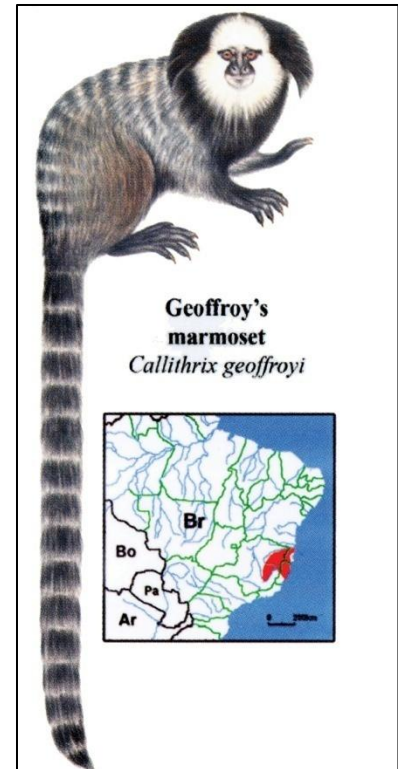
Callithrix jacchus (Linnaeus, 1758)

Common names:
Common marmoset
White-eared marmoset

IUCN Red List: Least Concern (LC)
CITES: Appendix 2
Regional Collection Plan: MONITORING by the TAG

Taxonomy:
This species used to include *C. aurita*, *C. flaviceps*, *C. geoffroyi*, *C. kuhlii*, and *C. penicillata*, now all regarded as full species.

Habitat & Distribution:
Common marmosets live in scrub, swamps and tree plantations, areas with a wide range of exudate producing trees in northeast Brazil, south as far as the rios Grande and São Francisco, west as far as the west bank of the Rio Parnaíba. They have been introduced into forests in north-east Brazil, south of the Rio São Francisco, south-east and south Brazil.

Morphology:
They have large white ear tufts. The tail has dark wide bands and pale narrow bands. They grow up to 188 mm with a tail length of 280 mm, and weigh up to 356 g. The caecum is specialised for exudate digestion.

Reproduction:
Weaning of infants occurs at around 2 months. They may reach sexual maturity at 12 months (females) and 16 months (males). The oestrous cycle lasts 28 days and gestation is 148 days. Females give birth to their first offspring at 20–24 months and breeding can occur with a 5–6 month interval. Usually they have twins, but one, three or even four offspring may result from pregnancy. Postpartum oestrus occurs within 9–10 days after a birth. The proceptive behaviour of the female is to stare at a male and flick her tongue in and out. During mating, the female looks back over the shoulder and opens her mouth.

Diet:
Common marmosets feed on fruit, gums and animal prey.

Behaviour:
They are more active in the early morning and late evening. The rest of the day is spent napping and grooming. Group size is usually around 8 individuals, varying between 3 and 15, but sometimes up to 20. This species has been imported to some regions and adapted to local conditions successfully. Vocalizations are, most commonly, a "phee", a twitter, a "tsik" and a squeal. Infants have play vocalisations.
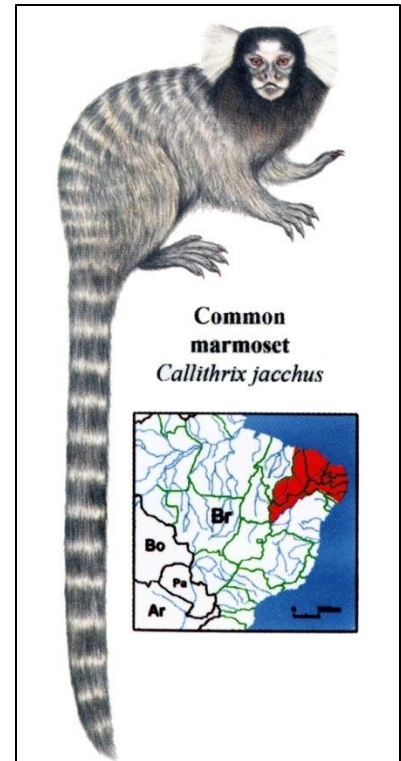
Callithrix kuhlii Coimbra-Filho, 1985

Common name:
Wied's black tufted-ear marmoset

IUCN Red List: Near Threatened (NT)
CITES: Appendix 2
Regional Collection Plan: MONITORING by the TAG

Taxonomy:
Hershkovitz (1977) considered *C. kuhlii* to be a hybrid of C*. jacchus penicillata* × *C. j. geoffroyi* (see Coimbra-Filho, 1985; Coimbra-Filho et al., 2006).

Habitat & Distribution:
They live in secondary, lowland, evergreen and semi-deciduous forests and forest edge in east Brazil, between the Rio de Contas and Rio Jequitinhonha, in southern Bahia.

Morphology:
Callithrix kuhlii has a greyish body flecked with black and grey bands. The crown and ears are black while the forehead, cheeks and throat are white. They weigh approximately 350–400 g. They are very similar to *Callithrix penicillata*.

Diet:
Fruit, insects, snails, gums and nectar.

Reproduction:
A species-specific silent open mouth display initiates mating but little information is available concerning reproduction.

Behaviour:
They generally forage at heights of 6–13 m, but also catch insects and spiders on the ground that are disturbed by army ants. These marmosets occasionally associate with *Leontopithecus chrysomelas*.
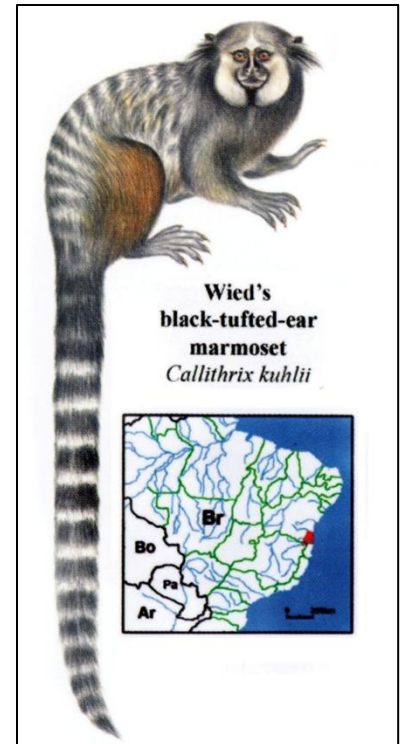
Callithrix penicillata (É. Geoffroy, 1812)

Common names:
Black-tufted ear marmoset
Black-pencilled marmoset

IUCN Red List:	Least Concern (LC)
CITES:	Appendix 2
Regional Collection Plan:	MONITORING by a person

Taxonomy:
Previously considered a subspecies of *Callithrix jacchus* (see Hershkovitz, 1977).

Habitat & Distribution:
Secondary forest, semi-deciduous forest and gallery forest in east central Brazil, in the states of Bahia, Minas Gerais, Goiás, and the southwest tip of Piauí, south of the rios Grande and São Francisco. Introduced into forests outside of its natural range in southeast Brazil.

Morphology:
These animals have black ear tufts and white forehead with light facial hair. Back and tail are banded. They grow up to 202–225 mm with a tail length of 287–325 mm and weigh between 182 and 225 g.

Reproduction:
There is no information on reproduction.

Diet:
Gums, fruit, animal prey (insects). There are reports of these marmosets, when in captivity, catching sparrows that fly into their cages.

Behaviour:
Average group size is 6.6 individuals varying between 3 and 9. They have smaller home ranges than other similar marmosets, a feature thought to be related to the high degree of gummivory they exhibit. They occasionally associate with *Leontopithecus chrysomelas*. Scent marking is most performed in gum-feeding holes. At least four vocalizations are recognised by humans, among which are an alarm call, a threat call and a loud, piercing contact call.
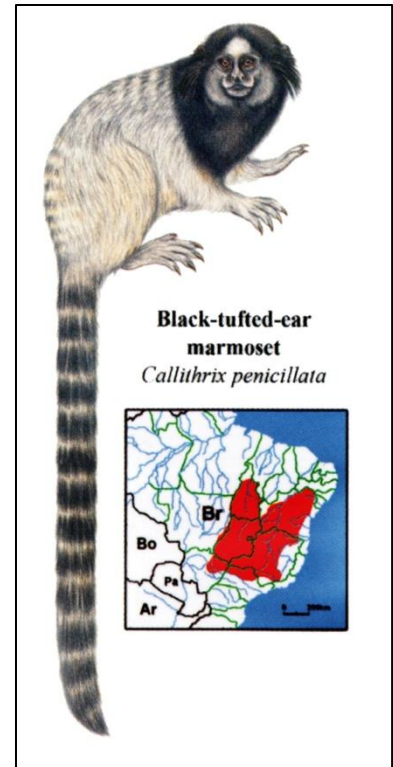
Cebuella pygmaea (Spix, 1823)

Common name:
Pygmy marmoset

IUCN Red List: Least Concern (LC)
CITES: Appendix 2
Regional Collection Plan: MONITORING by a person

Taxonomy:
Groves (2001, 2005) places it in the genus *Callithrix*. Although Hershkovitz (1977) recognizes no subspecific forms for *Cebuella*, Napier (1976) and Van Roosmalen and Van Roosmalen (1997) argued that a southerly (south of the Rio Solimões) form *niveiventris* Lönnberg, 1940 was valid (see Groves, 2001, 2005; Rylands et al., 2009). They are distinguishable by the presence or absence of speckles on the genital skin.

Habitat & Distribution:
Flood plain forest near rivers, edges of agricultural fields, secondary growth forest, bamboo thickets in central western Brazil, Ecuador and eastern Peru. The nominate subspecies occurs north of the Rio Solimões, while *C. p. niveiventris* occurs between the Rio Solimões and the Rio Madeira.

Morphology:
These marmosets are the smallest South American primates. They have a tawny agouti body and a tawny gold- grey head. They grow up to 136 mm with a tail length of 202 mm and weigh between 126 and 130g.

Reproduction:
Social structure is monogamous family groups with offspring from up to four litters. Weaning of infants occurs at 3 months and they are fully independent at five months. Gestation lasts 130–142 days. In the wild females give birth to their first offspring (usually two, occasionally three) at 24 months, and the next births occur at 5–7 month intervals. Post partum oestrus occurs within three weeks of a birth.

Diet:
Mainly gums (67%), fruit, nectar and animal prey.

Social behaviour:
Diurnal and arboreal. Locomotion is quadrupedal with some vertical clinging and leaping (up to 5m). Group size is usually around 6 individuals, varying between 1 and 15. Pygmy marmosets gouge holes in bark of trees and revisit them each day to produce a steady supply of gums. These marmosets regularly move home ranges, depending on exudate availability. Although they do not usually forage on the ground, they will go to the ground to catch grasshoppers. In the dry season *Saguinus* spp. may visit the gum trees of pygmy marmosets to feed. *S. nigricollis*, *S. imperator and S. fuscicollis* are found in the same area. Studies proved that they have at least 15 different vocalizations, including a long-distance contact call, an alarm call, a chorus call, and others. They have extremely small home ranges (approx. half a hectare).
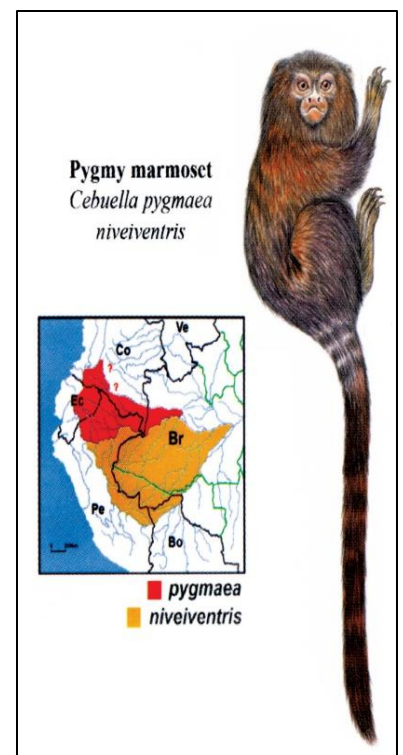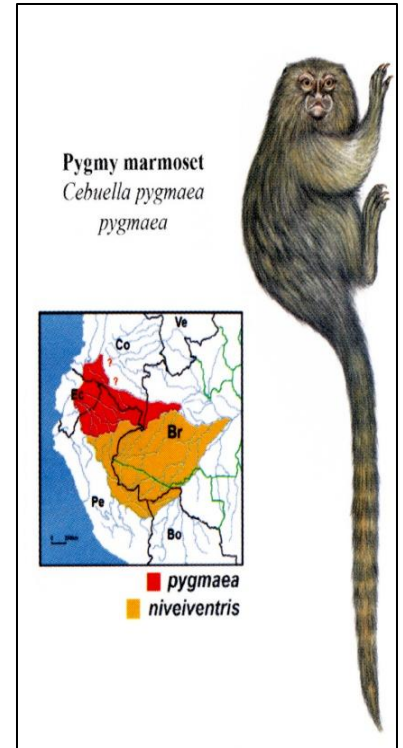
Leontopithecus caissara Lorini and Persson, 1990

Common name :
Black-faced lion tamarin

IUCN Red List: Critically Endangered (CR)
CITES: Appendix 1
Regional Collection Plan: DO NOT OBTAIN

Taxonomy:
Discovered and described in 1990. The possibility remains that *L. caissara* is a subspecies of *L. chrysopygus* (see Coimbra-Filho, 1990).

Habitat and Distribution:
Primary lowland coastal forest (*restinga*) with many epiphytic bromeliads and palms. Distribution limited to the coastal region of southern São Paulo state and northern Paraná State, Brazil.

Morphology:
Black-faced lion tamarins have a golden body and black face. There are no data available on body length or weight.

Reproduction:
No information available on life history or social structure, but is likely to be similar to the other lion tamarins.

Diet:
No data available.

Behaviour:
Nothing is known about group size.

Black-faced lion
tamarin
*Leontopithecus
caissara*
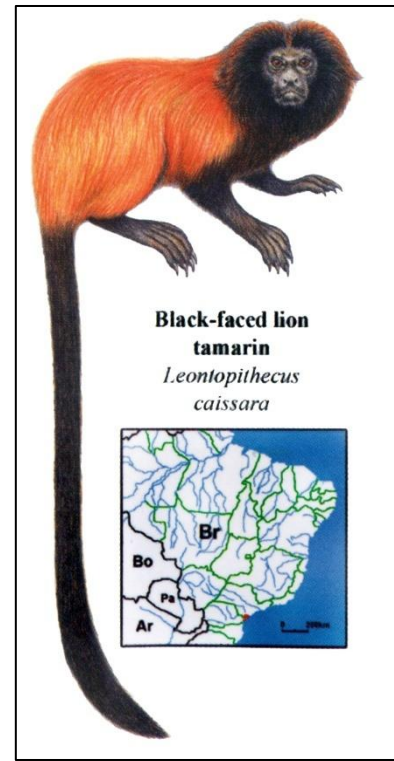
Leontopithecus chrysomelas (Kuhl, 1820)

Common name:
Golden-headed lion lamarin

IUCN Red List: Endangered (EN)
CITES: Appendix 1
Regional Collection Plan: EEP

Taxonomy:
The lion tamarins, *Leontopithecus*, are considered separate species following Della Serra (1951) and Rosenberger and Coimbra-Filho (1984) (see Rylands et al., 1993).

Habitat & Distribution:
Lowland forest, swamp, semi-deciduous and tall evergreen forest and shaded cacao plantations (*cabruca*) from sea level to 112 m in eastern Brazil, between the rios Jequitinhonha and de Contas.

Morphology:
Golden-headed lion tamarins have black fur all over the body, except for the head, arms, legs and part of the tail, which have golden fur. They grow up to 257 mm with a tail length of 376 mm and weigh between 480 and 700 g.

Reproduction:
Gestation is 128 days. Age of sexual maturity around 15 months. Subordinate females are not reproductively suppressed within their family groups, which may result in daughters becoming pregnant within groups.

Diet:
Fruit, gums, nectar and animal prey.

Behaviour:
Average group size is around 7 individuals, varying between 5 and 8. They forage at a height of 12–20 m and search for insects in bromeliads, leaf litter trapped in vine tangles, bark and tree holes. These animals associate with *C. kuhlii* and *C. penicillata*. They use tree holes in primary forest as sleeping sites.
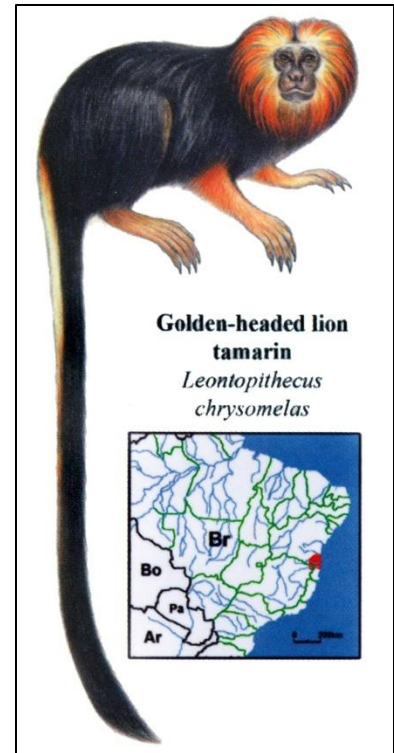
Leontopithecus chrysopygus (Mikan, 1823)

Common names:
Black lion tamarin
Golden-rumped lion tamarin

IUCN Red List: Endangered (EN)
CITES: Appendix 1
Regional Collection Plan: EEP

Black lion
tamarin
*Leontopithecus
chrysopygus*

Taxonomy:
The lion tamarins, *Leontopithecus*, are considered separate species following Della Serra (1951) and Rosenberger and Coimbra-Filho (1984) (see Rylands et al., 1993).

Habitat & Distribution:
These animals live in semideciduous riparian forest, to 100 m, in São Paulo State, in southeast Brazil, south of the Rio Tietê, north of the Rio Paranapanema, west to the Serra do Mar in the state of São Paulo.

Morphology:
Black lion tamarins are not entirely black: they have a gold rump and gold at the base of the tail. The extent of the gold colouring varies between individuals. They are the largest of the lion tamarins, growing up to around 294 mm with a tail length of 376 mm and weigh between 540 and 750 g.

Reproduction:
Similar to *L. chrysomelas*.

Diet:
Fruit, gums and animal prey.

Behaviour:
Group size varies between 2 and 7 individuals. They come to the ground to forage for prey. Their home range is larger than those of other three species of lion tamarins because the forest has no bromeliads and has a distinct dry season, thus differing from the habitat of the lion tamarin species found near the coast. They use tree holes as sleeping sites.
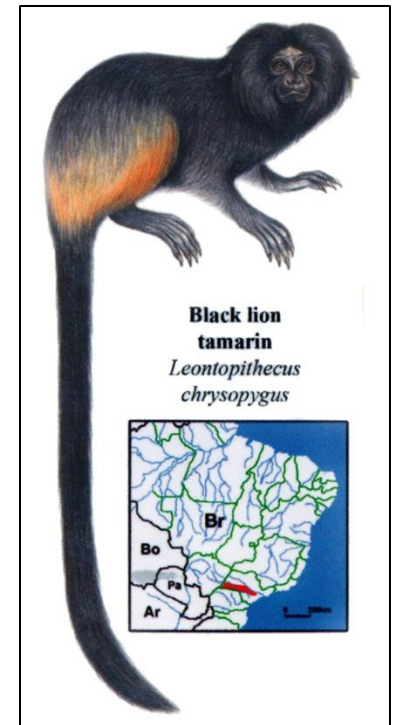
Leontopithecus rosalia (Linnaeus, 1766)

Common name:
Golden lion tamarin

IUCN Red List: Endangered (EN)
CITES: Appendix 1
Regional Collection Plan: EEP

Taxonomy:
The lion tamarins, *Leontopithecus*, are considered separate species following Della Serra (1951) and Rosenberger and Coimbra-Filho (1984) (see Rylands et al., 1993).

Habitat & Distribution:
Primary and secondary lowland forest from sea level to 500 m in southeast Brazil, in the basin of the Rio São João, Rio de Janeiro.

Morphology:
All golden, reddish, orange or buffy, except for grey hairless face. Some individuals have blackish bands on the tail or around the face. They grow up to 261 mm with a tail length of 370 mm and weigh between 361 and 680 g.

Reproduction:
Weaning occurs at 3 months. They reach sexual maturity at about 15 months. Oestrous cycle is 21 days. Females give birth after a gestation of 129 days and the next births occur at a 6–12 month interval. Post partum oestrus occurs 3–10 days after a birth. Shared infant care may not begin until a week or so after birth, but in established groups may be seen from day 1.

Diet:
Fruit, nectar, flowers, exudates, and animal prey, including insects and reptiles.

Behaviour:
Average group size is around 5 individuals, varying between 2 and 16. Sternal marking is more common than circumgenital. In captivity severe aggression has been reported to occur between adult females, even related females, within groups.

Reintroduction:
Leontopithecus rosalia has been the subject of a major reintroduction programme led by the National Zoological Park, Washington DC. By 1990, 75 individuals had been reintroduced. It has been estimated that the reintroduction programme has resulted in an 80% increase in available habitat for this species, as landowners are now prepared to set aside land for them. The golden lion tamarin programme has become a model success story for captive breeding and reintroduction
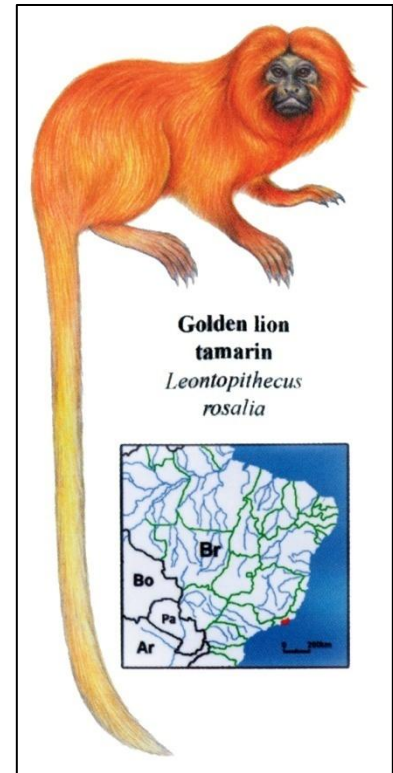
Mico acariensis (M.G.M. Van Roosmalen, T. Van Roosmalen, Mittermeier and Rylands, 2000)

Common name:
Rio Acarí marmoset

IUCN Red List: Data Deficient (DD)
CITES: Appendix 2
Regional Collection Plan: DO NOT OBTAIN

Taxonomy:
Described by Van Roosmalen et al. (2000)*.*

Habitat & Distribution:
These animals live in central Brazil, south of the Amazon between the Rio Acarí and the Rio Sucunduri. The southern limit of the range is not fully determined.

Morphology:
Van Roosmalen et al. (2000) describe the Rio Acarí marmoset as the most colourful of the Amazonian marmosets. It is a member of the *Mico argentatus* group with bright orange lower back, underparts, legs and proximal end of the black tail. It has predominantly white upper parts and a black pigmented muzzle.

Reproduction:
There is no information available regarding their life history.

Diet:
Probably fruit, exudates, animal preys and insects.

Behaviour:
No information available.

Rio Acarí
marmoset
*Mico
acariensis*
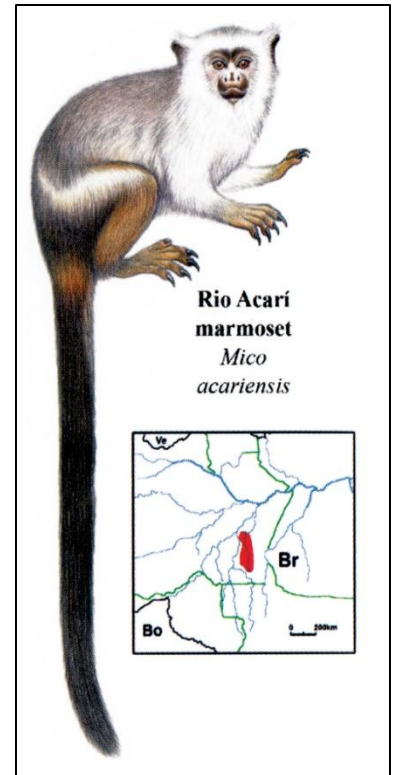
Mico argentatus (Linnaeus, 1766)

Common name:
Silvery marmoset

IUCN Red List: Least Concern (LC)
CITES: Appendix 2
Regional Collection Plan: MONITORING by a person

Taxonomy:
Previously considered to have subspecies *melanurus* and *leucippe* (see Hershkovitz, 1977) that are here considered full species.

Habitat & Distribution:
Silvery marmosets live in tropical rain forest, deciduous dry forest and seasonally flooded white-river forests (*várzea*), up to 900 m. Their range extends throughout central Brazil south of the Amazon and eastern Bolivia.

Morphology:
Mico argentatus grow to around 210 mm with a tail length around 305 mm. Weight is 320–457g. The body colour varies from white to dark-brown. The hairless ears and face are pink, mottled, or brownish in colour. The tail is black. Their caecum is specialized for exudate digestion.

Silvery
marmoset
Mico argentatus

Reproduction:
There is little information available on their life history but they follow a typical callitrichid pattern in captivity. Gestation is around 154 days. Females are sexually mature from about 15 months of age. Both sexes rhythmically lip-smack before mating.

Diet:
Silvery marmosets feed on fruit, animal prey and gums.

Behaviour:
As with life history, there is still little known about their social structure in the wild. In savannah habitats, groups will cross grassland from one tree clump to another. They use tree hollows, dense vegetation and vine tangles as sleeping sites. In the extreme eastern part of its range, this species is sympatric with *Saguinus niger*, and groups of the two species may form mixed-species associations. Glands in the circumgenital and sternal areas are used to scent-mark. They have a special play vocalization described as "ee-ee".
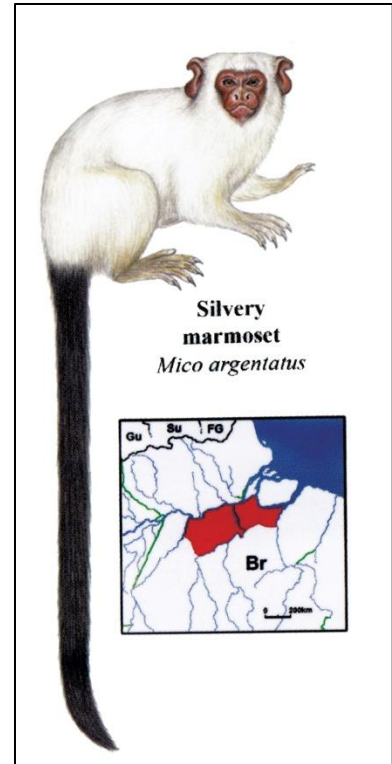
Mico chrysoleucus (Wagner, 1842)

Common name:
Golden-white tassel-ear marmoset

IUCN Red List: Data Deficient (DD)
CITES: Appendix 2
Regional Collection Plan: DO NOT OBTAIN

Taxonomy:
Previously considered a subspecies of *Callithrix humeralifer*
(see Hershkvoitz, 1977).

Habitat & Distribution:
Central Amazon in Brazil. Poorly known, it occurs in a north–south sliver, south of the Rio Amazonas, between the Rios Madeira and lower Aripuanã in the west and the Rio Canumã (= Cunumã) in the east.

Morphology:
Very pale marmoset, facial skin largely unpigmented, ears have long thick whitish tufts, head and trunk pale gold to whitish. Rump, tail, and fore- and hind limbs golden to orange.

Reproduction:
No specific information available at this time.

Diet:
Fruits, flowers, plant exudates (gums and nectar) and animal prey (including frogs, snails, lizards, spiders and insects).

Behaviour:
No specific information available at this time.
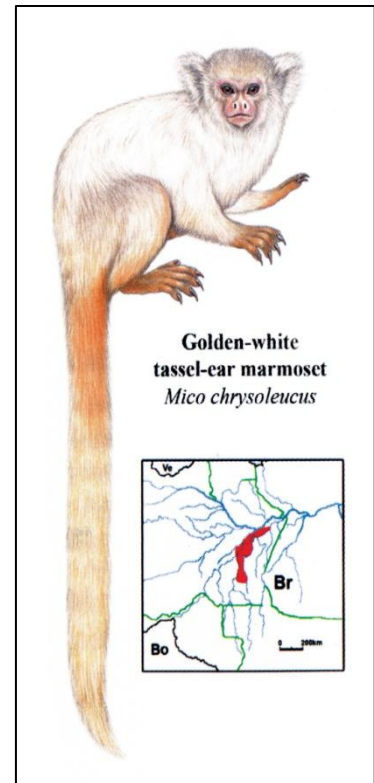
Mico emiliae (Thomas, 1920)

Common name:
Snethlage's marmoset

IUCN Red List: Data Deficient (DD)
CITES: Appendix 2
Regional Collection Plan: DO NOT OBTAIN

Taxonomy:
Hershkovitz (1977) considered this species to be merely a dark form of *M. argentatus*.

Habitat & Distribution:
In the south of the state of Pará in the Brazilian Amazon. It occurs south from the Rio Irirí to the southern margin of Rio Peixoto de Azevedo. The southern limits would evidently not be beyond the headwaters and upper Rio Paraguai, approximately 14º30'S, where *M. melanurus* occurs.

Morphology:
Blackish crown and greyish-brown back. Whitish face, cheeks and forehead, and absence of of whitish hip patch distinguish it from *M. melanurus*. Tail black.

Reproduction:
No specific information available at this time.

Diet:
Fruits, flowers, plant exudates (gums and nectar) and animal prey (including frogs, snails, lizards, spiders and insects).

Behaviour:
No specific information available at this time.
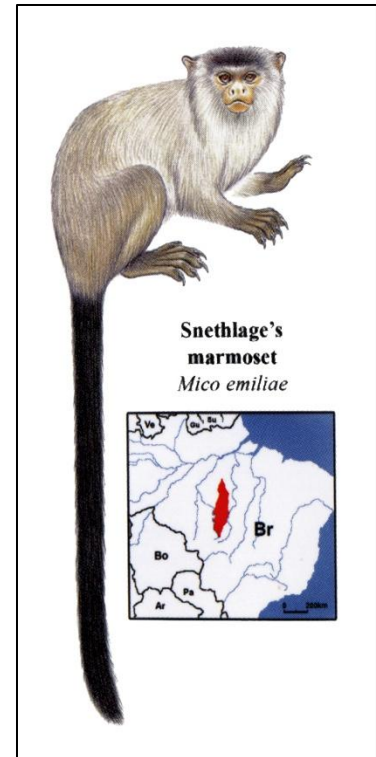
Mico humeralifer (É. Geoffroy, 1812)

Common name:
Black and white tassel-ear marmoset

IUCN Red List: Data Deficient (DD)
CITES: Appendix 2
Regional Collection Plan: DO NOT OBTAIN

Taxonomy:
Previously considered to have subspecies *chrysoleucus* and *intermedius* (see Hershkovitz, 1977) that are here considered full species.

Habitat & Distribution:
These animals live in secondary forest with dense vines, in central Brazil, south of the Amazon.

Morphology:
Their colour varies, but they all have pale ear tufts, like fans. Their tail is distinctly or faintly banded. They measure up to 215 mm with a tail length of 355 mm and weigh between 280 and 310 g.

Reproduction:
There is no information available regarding their life history.

Diet:
Fruit, exudates, animal prey and insects.

Behaviour:
Group size is reported as varying between 8 and 15. Like some other marmosets, these have been observed following army ants and catching the insects they disturb. Scent-marking is performed by rubbing tree branches with the inside part of the arms. They vibrate their tongues to make "cricket-like" calls. They use vine-covered trees as sleeping sites.

Black-and-white
tassel-ear marmoset
Mico humeralifer
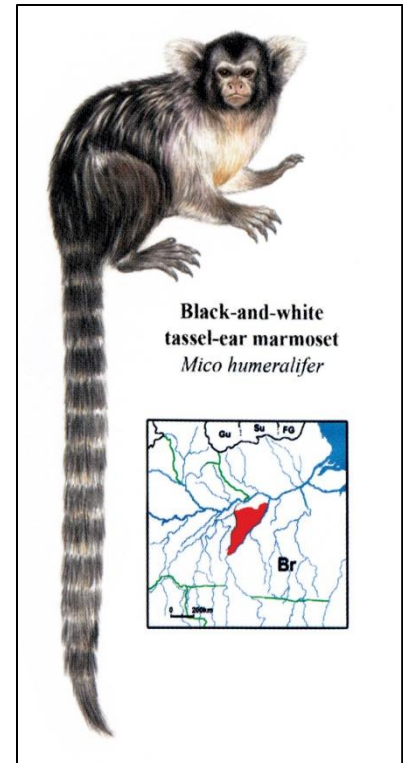
Mico intermedius (Hershkovitz, 1977)

Common name:
Aripuanã marmoset

IUCN Red List: Data Deficient (DD)
CITES: Appendix 2
Regional Collection Plan: DO NOT OBTAIN

Taxonomy:
Previously considered to be a subspecies of *Callithrix humeralifer*
(see Hershkovitz, 1977).

Habitat & Distribution:
This species occurs in ther Central Amazon, between the rios Roosevelt and Aripuanã, including the entire basin of the Rio Guariba. *Mico intermedius* and *M. melanurus* are not sympatric between the Rios Aripuanã and Roosevelt as was supposed by Hershkovitz (1977).

Morphology:
Similar to *M. melanurus* in such aspects as the distinct pale thigh stripe, similarly coloured hindquarters, a greyish crown (paler than *M. melanurus*), and the lack of an ear-tuft (it has a rudimentary tuft from behind the pinna only and not the well-developed tuft from within and around the pinna as in *M. humeralifer*). The face is variably depigmented (some individuals have quite dark greyish faces), the forequarters are paler, and varying parts of the tail are pale rather than black, when compared to *M. melanurus*.

Reproduction:
No specific information available at this time.

Diet:
Fruits, small animal prey, especially insects, plant exudates (gums and nectar).

Behaviour:
No specific information available at this time.
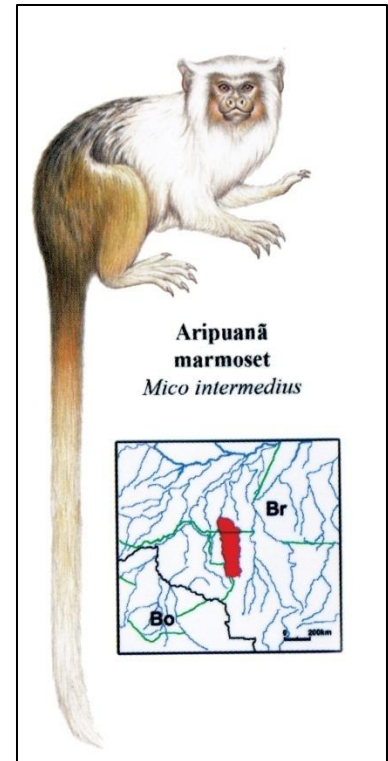
Mico leucippe (Thomas, 1922)

Common name:
Golden-white bare-ear marmoset

IUCN Red List: Vulnerable (VU)
CITES: Appendix 2
Regional Collection Plan: DO NOT OBTAIN

Taxonomy:
Previously considered to be a subspecies of *Callithrix argentata* (see Hershkovitz, 1977).

Habitat & Distribution:
This species occurs in the central Amazon of Brazil, in a small area in the state of Pará, between the rios Cuparí and Tapajós (right bank of the Rio Tapajós), south to the Rio Jamanxim.

Morphology:
Head and body predominantly whitish, tail and feet pale gold, facial skin and ears unpigmented or mottled.

Reproduction:
No specific information available at this time.

Diet:
Fruits, flowers, plant exudates (gums and nectar) and animal prey (including frogs, snails, lizards, spiders and insects).

Behaviour:
No specific information available at this time.

Golden-white
bare-ear
marmoset
Mico leucippe
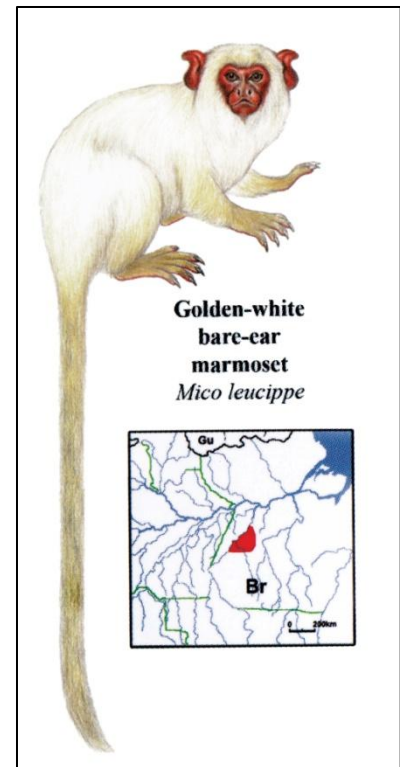
Mico manicorensis (M.G.M. Van Roosmalen, T. Van Roosmalen, Mittermeier and Rylands, 2000)

Common name:
Manicoré marmoset

IUCN Red List: Data Deficient (DD)
CITES: Appendix 2
Regional Collection Plan: DO NOT OBTAIN

Taxonomy:
Described by Van Roosmalen et al. (2000) in the genus *Callithrix.*

Habitat & Distribution:
These animals live in central Brazil, south of the Amazon. Range not fully determined.

Morphology:
A member of the *Mico argentatus* group, the cap of the head is light grey, the rest of the pelage a drab white with orange legs. The tail is black.

Reproduction:
There is no information available regarding their life history.

Diet:
Probably fruit, exudates, animal prey and insects.

Behaviour:
No information available.

Manicoré
marmoset
*Mico
manicorensis*
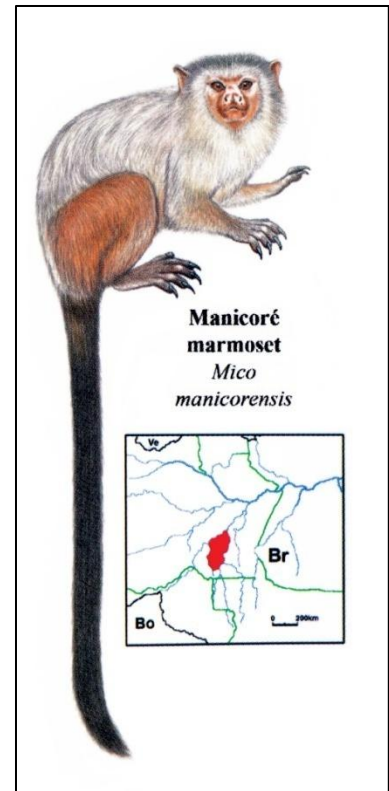
Mico marcai (Alperin, 1993)

Common name:
Marca's marmoset

IUCN Red List   Data Deficient (DD)
CITES: Appendix 2
Regional Collection Plan: DO NOT OBTAIN

Taxonomy:
First described as a subspecies of *Callithrix argentata* (see Alperin, 1993).

Habitat & Distribution:
The central Amazon, Brazil; known only from its type locality, the mouth of
the Rio Castanho (= Rio Roosevelt), left bank tributary of the Rio Aripuanã,
in the state of Amazonas.

Morphology:
Dark face, unpigmented around the nostrils and covered with small hairs;
crown dark brown; with hairs paler near to the base, white patch between
the eyes, back of the neck and mantle showing a brown pattern (lightly
ochre);
middle and lower back reddish brown washed with brown and showing a
variegated belt at the height of the hips and base of the tail; forelimbs, arm
and forearm slightly paler than the back, hands slightly hirsute with the same colour as the forelimbs, thighs
quite distinct from the rest of the body with a distinctly ochraceous colour on the inner and outer surfaces; tail
dark brown, the first proximal inch quite distinct with ochraceous rings; the ventrum is reddish. Differs from *M.
leucippe* and *M. argentatus* in a having very distinct coloration of the mantle. and from *M. melanurus* in not
having the white patches on the hips, besides the white patch on the forehead. It differs from *M. emiliae* in
having pale hands and feet, and a dark brown forehead.
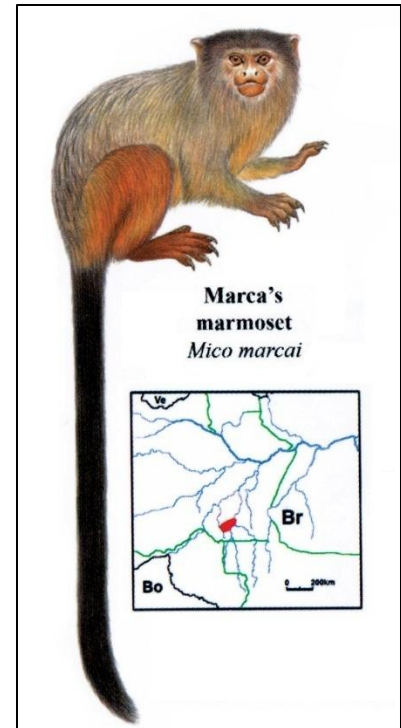
Reproduction:

No specific information available at this time.

Diet:
Fruits, flowers, plant exudates (gums and nectar) and animal prey (including frogs, snails, lizards, spiders and
insects).

Behaviour:
No specific information available at this time.

Mico mauesi (Mittermeier, Schwarz and Ayres, 1992)

Common name :
Maués marmoset

IUCN Red List: Least Concern (LC)
CITES: Appendix 2
Regional Collection Plan: DO NOT OBTAIN

Taxonomy:
Described by Mittermeier et al. (1992) in the genus *Callithrix*.

Habitat & Distribution:
Primary rain forest in the central Amazon, south of the Rio Amazonas. Limited in the north by the Paraná do Urariá, in the east by the Rio Maués-Açu, in the west by the Rio Abacaxis, and in the south, between the rios Tapajós and Sucunduri, to the Igarapé do Surubim.

Morphology:
They have a dark mantle and erect ear tufts. Back is banded. They grow up to 226 mm with a tail length ranging from 339 to 376 mm. There is no information on body mass.

Reproduction:
There is no information available regarding life history or social structure.

Diet:
Nothing specific known.

Behaviour:
No information on behaviour has been published.

Maués marmoset
Mico mauesi
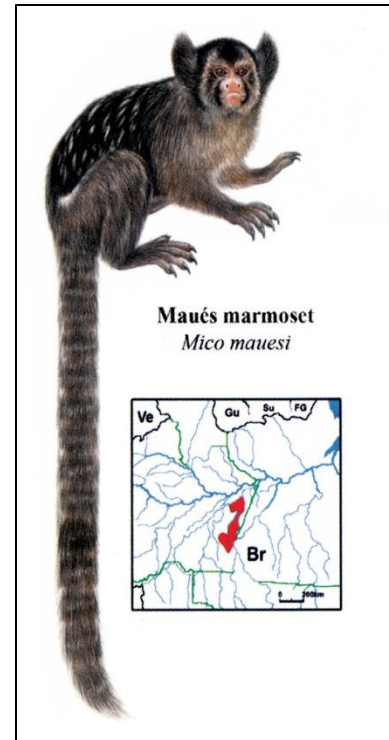
Mico melanurus (É. Geoffroy, 1812)

Common name:
Black-tailed marmoset

IUCN Red List: Least Concern (LC)
CITES: Appendix 2
Regional Collection Plan: MONITORING by a person

Taxonomy:
Previously considered to be a subspecies of *Callithrix argentata*
(see Hershkovitz, 1977).

Habitat & Distribution:
In the south central Amazon and Pantanal of the Mato Grosso of Brazil, extending into Bolivia and Paraguay. It ranges south from the vicinity of the Serra do Sucunduri, interfluvium of rios Aripuanã and Juruena, into Mato Grosso, Pantanal and Bolivia, east of the Río Mamoré, and in the northeastern Paraguayan Chaco to approximately 20ºS.

Morphology:
Facial skin and ears deeply pigmented, although sometimes there is mottling around the nose and muzzle. Forehead, crown and lower back predominantly
brown, tail blackish; prominent whitish, pale hip and thigh patch (along dorsal surface of thigh), defined from brownish legs and sides of body. No ear tufts.

Reproduction:
No specific information available at this time.

Diet:
Fruits, flowers, plant exudates (gums and nectar) and animal prey (including frogs, snails, lizards, spiders and insects).

Behaviour:
No specific information available at this time.
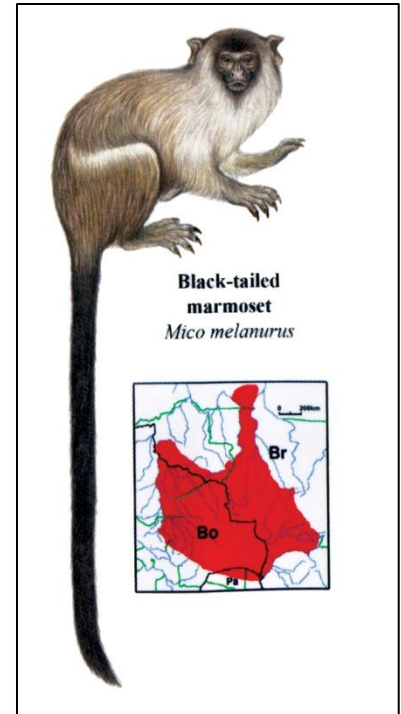
Mico nigriceps (Ferrari and Lopes, 1992)

Common name:
Black-headed marmoset

IUCN Red List: Data Deficient (DD)
CITES: Appendix 2
Regional Collection Plan: DO NOT OBTAIN

Taxonomy:
First described by Ferrari and Lopes (1992) in the genus *Callithrix.*

Habitat & Distribution:
Lowland rain forest and edge, in the southern central Amazon in Brazil.

Morphology:
These animals get their name from their black crown. They have a hairless black face with mottling, yellow lips and thighs, and a brown/black tail. The underparts are yellow to orange. Males have white hairless scrotum. Usually they grow up to an average of 200 mm with a tail length of 320 mm, and weigh around 370 g.

Reproduction:
No data available.

Diet:
C. nigriceps feed on gum, fruit, seeds and insects (based on gut analysis).

Behaviour:
Nothing is known about group size. Locomotion is quadrupedal. No field studies have yet been published on this recently described species. It has no protected area.
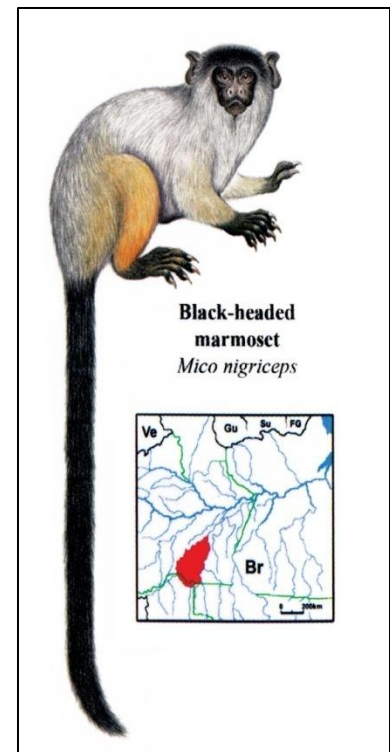
Mico saterei (Silva Jr. and Noronha, 1998)

Common name:
Sateré marmoset

IUCN Red List: Data Deficient (DD)
CITES: Appendix 2
Regional Collection Plan: DO NOT OBTAIN

Sateré marmoset
Mico saterei

Taxonomy:
First described by Silva Jr. and Noronha (1998) in the genus *Callithrix*.

Habitat & Distribution:
Central Amazon in Brazil, south of the Rio Amazonas. Limited in the north by the Paraná do Urariá, in the east by the Rio Abacaxis, in the west by the rios Canumã and Sucunduri, and in the south, between rios Sucunduri and Abacaxis, to the vicinity of Igarapé do Arreganhado, an affluent of Sucunduri.

Morphology:
A bare-eared and distinctive marmoset. Most distinctive character is the morphology of the external genitalia. Both sexes and all age classes have two lateral pendular skin appendages. In the male, they are a narrowing of the inferior part of the scrotal lobes; in the female, they appear in the inguinal region, anterior to the vagina. The skin of the external genitalia is bright orange. Unpigmented facial skin except in the lateral parts of neck and small pigmented patches around the nose and mouth and above the eyes. Pigmented ears and a strong reddish orange patch on the posterior part of the ear lobe. *Mico saterei* has a distinct mantle contrasting with the dorsum and anterior limbs, and a well marked blackish-grey crown. Legs reddish brown; bright brownish-orange ventrum.

Reproduction:
No specific information available at this time.

Diet:
Fruits, flowers, plant exudates (gums and nectar) and animal prey (including frogs, snails, lizards, spiders and insects.

Behaviour:
No specific information available at this time.
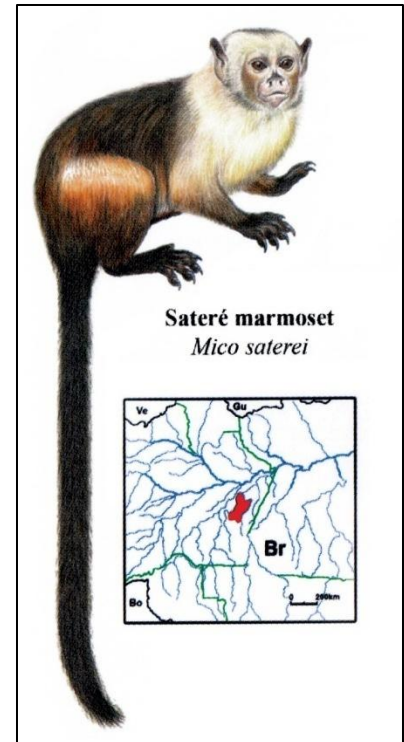
Mico rondoni (Ferrari, Sena, Schneider and Silva Jr., 2010)

Common name:
Rondon's marmoset

IUCN Red List: Vulnerable (VU)
CITES: Appendix 2
Regional Collection Plan: DO NOT OBTAIN

Rondon's marmoset
Mico rondoni

Taxonomy:
This species, for many years considered as *Callithrix emiliae*, following Vivo (1985), was formally described as a distinct species by Ferrari et al. (2010). Recognizing that this marmoset was not in fact a population of the form *emiliae* known from the Iriri basin to east, Rylands et al. (2009; and earlier publications) referred to this species as *Mico* cf. *emiliae*, awaiting the publication of its true taxonomic status by Ferrari et al.

Habitat & Distribution:
South-central Amazon in Brazil. The geographic range is delimited by the rios Mamoré, Madeira and Jiparaná rivers to the west, north, and east, respectively, and the Serra dos Pacaás Novos to the south, where it is replaced by *Mico melanurus*.

Morphology:
Silvery grey. Diagnostic features include the presence of blackish hairs on the forehead and sides of face, a distinct whitish patch, contrasting with the crown, on the centre of the forehead, blackish crown pelage that extends to the back of the head and to the front of the ears, lower dorsum and proximal portion of legs greyish brown, darkening to almost black on the tail, the fur on the legs darkens gradually to reddish brown on the shin, blackish on the ankle. Adult body weight: mean 330 g (n = 17) (Ferrari et al., 2010).

Reproduction:
No specific information available at this time.

Diet:
Fruits, insects, plant exudates (gums and nectar) (Ferrari and Martins, 1992).

Behaviour:
In the wild it is sympatric with, and sometimes associates with, *Saguinus fuscicollis weddelli*.
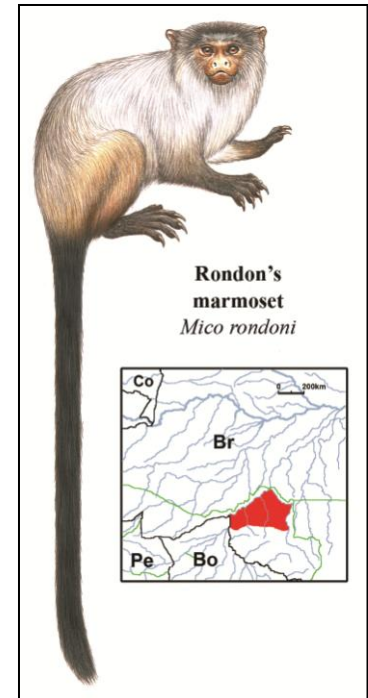
Saguinus bicolor (Spix, 1823)

Common name :
Pied tamarin

IUCN Red List: Endangered (EN)
CITES: Appendix 1
Regional Collection Plan: EEP

Taxonomy:
Previously comprising three subspecies – *S. b. bicolor*, *S. b. martinsi* and *S. b. ochraceus* (see Hershkovitz, 1977). Rylands et al. (2000) and Groves (2001)) place *S. bicolor* as a separate species, with the other two forms being subspecies of *S. martinsi.*

Habitat & Distribution:
Secondary forest, swamp, forest edge, white sand forest in north Brazil. *Saguinus bicolor* occurs north of the Rio Amazonas, east of the Rio Negro, in the vicinity of Manaus, the capital of the state of Amazonas, Brazil. It has a restricted range, extending only approximately 40–45 km to the north of Manaus, as far as the Rio Cuieiras, and east as far as the Rio Urubu.

Morphology:
Pied bare-face tamarins get their name from their black hairless face and ears. They grow up to 208–283 mm with a tail length between 335 and 420 mm, and weigh around 430 g.

Reproduction:
Little is known of this species in the field. Usually females give birth to two offspring, with a birth interval of 6 months. Gestation and oestrous cycle length are known from captivity – approximately 160 and 21 days respectively.

Diet:
Fruit, gum, animal prey, flowers, seedpod gums (dry season).

Behaviour:
Group size varies between 2 and 8 individuals. They use a stealthy approach to hunt and capture insects on leaves and branches at all levels of the canopy, up to 20m.

Pied bare-face
tamarin
Saguinus bicolor
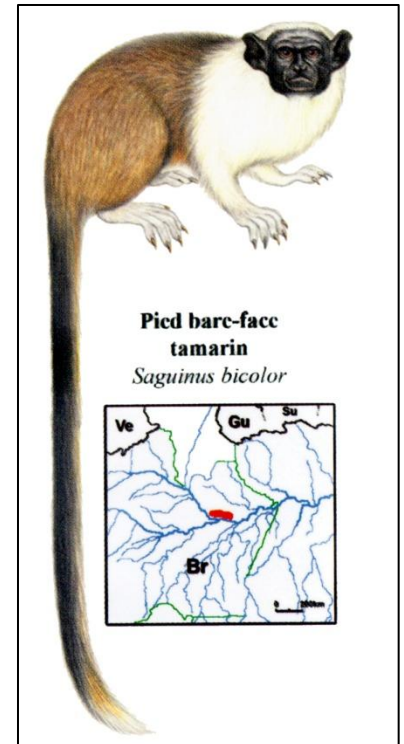
Saguinus fuscicollis (Spix, 1823)

Common name:
Saddle-back tamarin

IUCN Red List: Least Concern (LC)
                           S. f. primitivus Data Deficient (DD)
                           S. f. mura Not Evaluated (NE)
CITES: Appendix 2
Regional Collection Plan: MONITORING by the TAG

Spix's
saddle-back
tamarin
*Saguinus fuscicollis
fuscicollis*

Taxonomy:
Hershkovitz (1977) recognized 14 subspecies: *S. f. fuscicollis*, *S. f. nigrifrons*, *S. f. leucogenys*, *S. f. weddelli*, *S. f. cruzlimai*, *S. f. primitivus*, *S. f. illigeri*, *S. f. lagonotus*, *S. f. tripartitus*, *S. f. fuscus*, *S. f. avilapiresi*, *S f. acrensis*, *S. f. melanoleucus*, and *S. f. crandalli*. The form *tripartitus* was subsequently considered to be a distinct species because of the (erroneous) supposition that it was sympatric with *S. f. lagonotus* (see Thorington, 1988). The subspecies *S. f. acrensis* is a naturally occurring hybrid of *S. f. fuscicollis* and *S. f. melanoleucus* (see Peres et al., 1996). *Saguinus f. melanoleucus* is now considered a distinct species with the form *crandalli* as a subspecies. *Saguinus f. mura* was described in 2009 (Röhe et al., 2009). Eleven subspecies are therefore currently recognized.

Habitat & Distribution:
Primary, secondary and lowland forest and in Brazil, Bolivia, Peru, Ecuador and Colombia, west of the Rio Madeira and Rio Mamoré (except for an incursion by *S. f. weddelli* east of the Rio Madeira in the state of Rondônia) to the Andes and north to the Rio Caquetá in Colombia (*S. f. fuscus*).

Morphology:
Saguinus fuscicollis have large bare ears and a hairy face. Fur colour varies with the subspecies. They grow up to 213–220 mm with a tail length of 318–324 mm, and weigh around 387–403 g.

Reproduction:
Weaning of infants occurs at 3 months. Sexual maturity occurs at about 15 months. Gestation is 145–152 days. Females give birth to their first offspring at 18 months and other births may occur at 6–12 month intervals.

Diet:
Wet season: fruit, sap, petioles. Dry season: nectar, fruit, sap, animal prey.

Behaviour:
Average group size is 5–8 individuals. Saddleback tamarins form mixed-species associations with many other species in different parts of their range. These include *M. emiliae*, *C. goeldii*, *Callicebus moloch*, *C. torquatus*, *S. imperator*, *S. nigricollis*, *S. mystax* and *S. labiatus*. Scent mark communication in this species has been intensely studied. They have at least 13 vocalisations, including a soft trill contact call, a long distance loud whistle and an alarm call, to which emperor tamarins respond (and vice-versa). They use holes in trees and tangles as sleeping sites.

Weddell's saddle-back tamarin
Saguinus fuscicollis weddelli

Illiger's saddle-back tamarin
Saguinus fuscicollis illigeri

Cruz Lima's saddle-back tamarin
Saguinus fuscicollis cruzlimai

Red-mantle saddle-back tamarin
Saguinus fuscicollis lagonotus

Hershkovitz's saddle-back tamarin
Saguinus fuscicollis primitivus

Andean saddle-back tamarin
Saguinus fuscicollis leucogenys

Lesson's
saddle-back
tamarin
*Saguinus fuscicollis
fuscus*

Geoffroy's
saddle-back
tamarin
*Saguinus fuscicollis
nigrifrons*

Ávila-Pires'
saddle-back
tamarin
*Saguinus fuscicollis
avilapiresi*

Saguinus geoffroyi (Pucheran, 1845)

Common name:
Geoffroy's tamarin

IUCN Red List: Least Concern (LC)
CITES: Appendix 1
Regional Collection Plan: DO NOT OBTAIN

Taxonomy:
Hershkovitz (1977) considered *Saguinus geoffroyi* to be a subspecies of *S. oedipus*. Comparative morphological studies by Hanihara and Natori (1987), Moore and Cheverud (1992) and Skinner (1991) argued for them being separate species (Rylands, 1993). Groves (2001, 2005) listed *S. geoffroyi* and *S. oedipus* as separate species.

Habitat & Distribution:
Primary, secondary, moist tropical and dry forests. They prefer secondary growth with large trees. Often they are seen near shifting cultivated areas. Their range extends from southern northern Colombia into central and east Panama. In Colombia the species occurs along the Pacific coast, south as far as Río San Juan.

Morphology:
These animals have a flecked yellow, brown and black dorsal pelage. The ventrum is white. The face is almost bare and they have a triangular crown of short white fur, while the hair on the nape of the neck is reddish in colour. Their tail is red with a black tip. They grow up to 247–252 mm and weigh around 545 g.

Reproduction:
Weaning of infants occurs at 2–3 months. They reach sexual maturity at about 15 months. There is no information on oestrous cycle, age of first birth or birth interval. In the wild, the mating season occurs between January and February and the birth season is from April to June.

Diet:
Fruit, animal prey, flowers, gums and buds. Females eat exudates during gestation and lactation.

Behaviour:
Group size varies between 3 and 7 individuals. Scent-marking is made particularly where their home range overlaps with other groups. They have several vocalizations: long whistle for a long distance intragroup call, trills and long rasps for hostile situations. They use large emergent trees as sleeping sites.
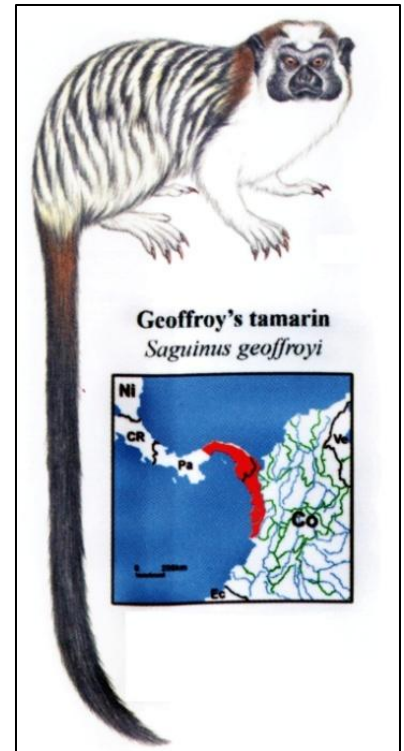
Saguinus imperator (Goeldi, 1907)

Common name:
Emperor tamarin (black-chinned and bearded)

IUCN Red List: Least Concern (LC)
CITES: Appendix 2
Regional Collection Plan: *S. i. imperator* DO NOT OBTAIN
                            S. i. subgrisescens EEP

Taxonomy:
Two subspecies; *S. i. imperator* and *S. i. subgrisescens* (see Hershkovitz, 1979).

Habitat & Distribution:
Primarily lowland, evergreen and broadleaf forests up to 300 m, in Peru, Brazil and Bolivia in the southwest Amazon, east of the upper Rio Purus, between the rios Purus and Acre (*S. i. imperator*) and east of the upper Rio Juruá to the rios Tarauacá and Juruparí, west to the ríos Urubamba and Inuya; and south of Río Tahuamanú (*S. i. subgrisescens*).

Morphology:
Emperor tamarins get their name form the regal appearance of their long white moustache. They have a black head, greyish brown body, a red-orange tail and white underparts. They grow up to 230–255 mm with a tail length of 390–415 mm and weight around 450 g. The subspecies can be distinguished by the shape of the moustache.

Reproduction:
There is little information regarding this species life history (weaning, sexual maturity, oestrous cycle, age of first birth, interbirth interval). Usually females give birth to two offspring, after a gestation of 140–145 days.

Diet:
Fruit, nectar, sap, fungi, flowers and animal prey. They also eat gum, in the late dry season and early wet season.

Social behaviour:
Average group size is four. They forage for insects on leaves, vines and branches in lower and middle levels by scanning and quickly attacking them. Emperor tamarins associate with *Saguinus fuscicollis*, with whom they share territory and are dominant to. Occasionally they associate with *Callicebus moloch*. Vocalizations include whistles, chirps and long, descending whistles. They announce their presence with loud vocalizations near territorial boundaries. They respond to the alarm calls of *Saguinus fuscicollis* and vice-versa. Group members sleep closely together in large vine-covered and isolated trees.

Black-chinned emperor tamarin
Saguinus imperator imperator

Bearded emperor tamarin
Saguinus imperator subgrisescens
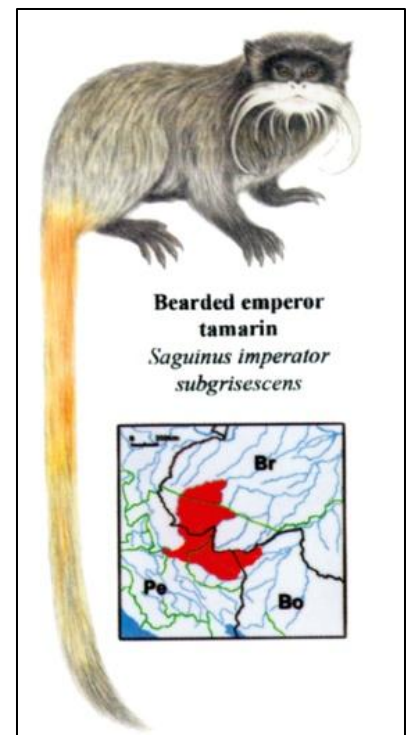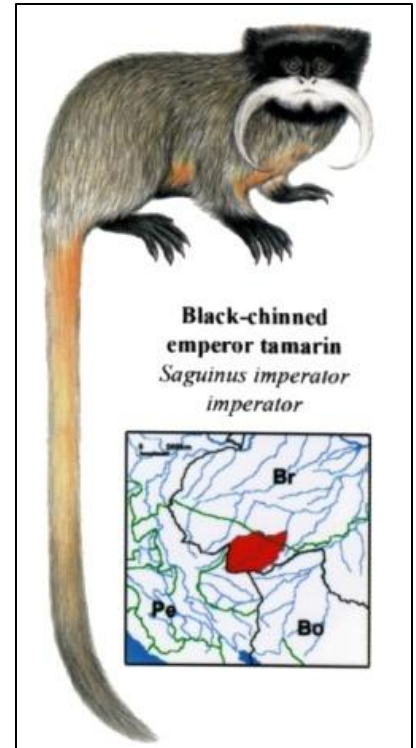
Saguinus inustus (Schwarz, 1951)

Common name:
Mottle-faced tamarin

IUCN Red List: Least Concern (LC)
CITES: Appendix 2
Regional Collection Plan: DO NOT OBTAIN

Taxonomy:
Monotypic. Defler (2004) indicated that there may be subspecific variation.

Habitat & Distribution:
Rain forest in northern Brazil and southern Colombia. Between the upper rios Negro and Japurá–Caquetá, north to the ríos Apaporis and upper Guaviare.

Morphology:
Mottled-faced tamarins have a black body and naked black ears. The muzzle has a white patch of skin on each side and the genitalia are white. They grow up to around 233 mm with a tail length of 366 mm. There is no information on weight.

Reproduction:
There is no information available on life history or social structure.

Mottled-face tamarin
Saguinus inustus

Diet:
No information available.

Social behaviour:
Nothing is known about group size. No field studies had been published as of 1999.
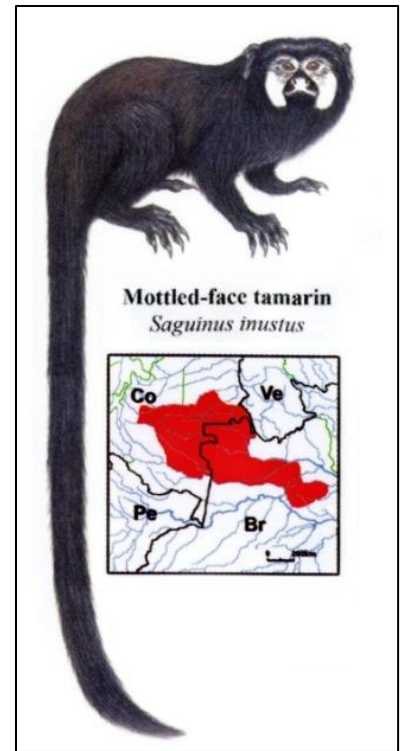
Saguinus labiatus (É. Geoffroy, 1812)

Common names:
Red-bellied tamarin
White-lipped tamarin
Thomas' moustached tamarin

IUCN Red List: Least Concern (LC)
CITES: Appendix 2
Regional Collection Plan: ESB

Taxonomy:
Three subspecies: *S. l. labiatus*, *S. l. rufiventer* (Gray, 1843) and *S. l. thomasi* (Goeldi, 1907). *Saguinus l. rufiventer* recognized as valid by Groves (2001), but considered a junior synonym of *S. l. labiatus* by Hershkovitz (1977).

Habitat & Distribution:
In primary and secondary forest between the rios Japurá and Solimões, from Auatí-Paraná to Rio Tonantins (*S. l. thomasi*]), between the rios Madeira and Purus, south from the Rio Solimões to the north bank of the Rio Ipixuna (*S. l. rufiventer* [Gray, 1843]), and south from Rio Ipixuna, to the north of Río Tahuamanú (Bolivia and Peru) in southeast Peru (*S. l. labiatus*).

Southern red-bellied tamarin
Saguinus labiatus labiatus

Morphology:
Red-bellied tamarins have white hair around their lips and nose. Back and tail are black with silvery highlights. On the nape of the head they have a white triangle. Underparts are bright reddish orange. They grow up to around 261 mm with a tail length of 387 mm and weigh around 455–460 g.

Thomas's red-bellied tamarin
Saguinus labiatu thomasi
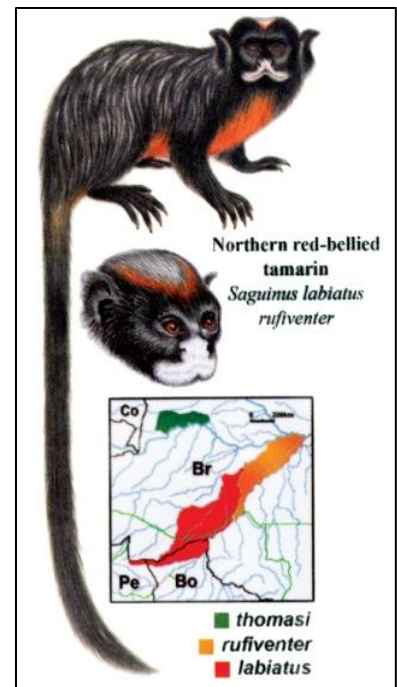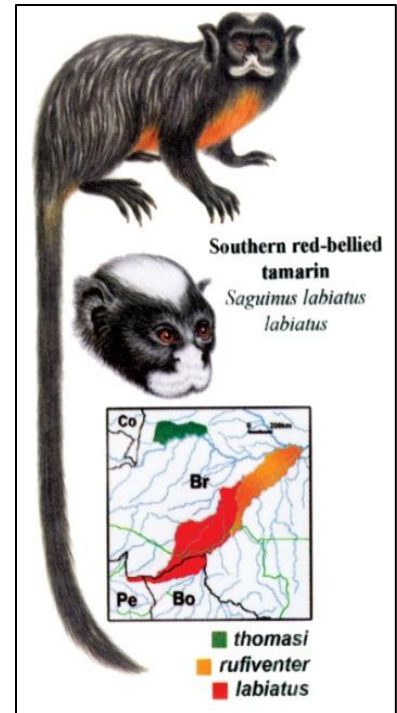
Reproduction:
Gestation lasts 140–150 days. Most groups have one breeding female. Solitary males have been observed.

Diet:
Fruit, insects, exudates and nectar.

Behaviour:
Group size varies between 2 and 13. These animals forage and travel (occasionally together with *Saguinus fuscicollis*, who forage at lower heights) at heights of 3–32m. In captivity, males groom females more often than vice-versa. These tamarins associate with *Callimico goeldii* and *Saguinus f. weddelli* and defend a common territory. Females are reported to scent mark more than males. Infants have a play vocalization. They use forks of trees about 12–18 m above the ground as sleeping sites.

Northern red-bellied tamarin
Saguinus labiatus rufiventer

Saguinus leucopus (Günther, 1877)

Common names:
Silvery-brown tamarin
White-footed tamarin

IUCN Red List: Endangered (EN)
CITES: Appendix 1
Regional Collection Plan: EEP when animals are imported into
                                   the region

Taxonomy:
Related to the *Saguinus oedipus*, bare-face tamarin, group (Hershkovitz, 1977).

Habitat & Distribution:
Saguinus leucopus live in primary and secondary forest near streams up to 1500 m. They usually prefer low and thick secondary growth and edge habitats. The species is endemic to Colombia, where it occurs centrally to the north of the country between the ríos Magdalena and Cauca from their confluence, south into west Caldas and north Tolima.

Morphology:
They have a brown body, whitish arms and legs, reddish orange underparts
nd blackish tails. They grow up to a length of 241–244 mm and weigh about 440 g.

Reproduction:
There is no information available regarding life history or sexual behaviour, except that infants have been seen in June in the wild.

Diet:
Their diet is primarily fruit, although it is likely that insects and exudates are eaten as well.

Behaviour:
Group size varies between 2 and 15 individuals. They use all heights of the forest. The most common vocalization of this species is the tee-tee, which is said to be "shrill and somewhat melancholic".
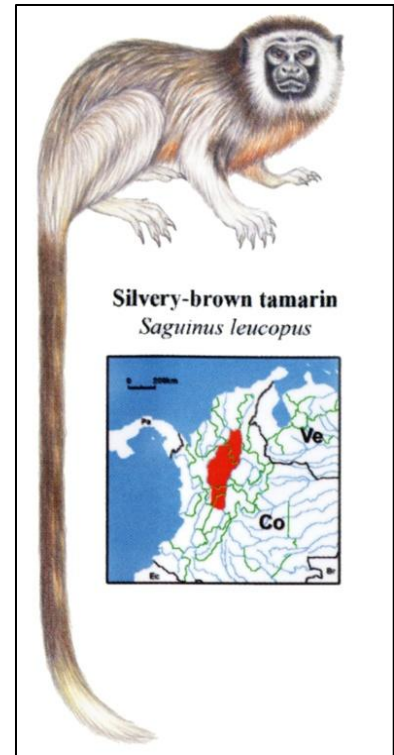
Saguinus martinsi (Thomas, 1912)

Common name:
Martin's bare-face tamarin
Ochraceous bare-face tamarin

IUCN Red List: Least Concern (LC)
CITES: Appendix 2
Regional Collection Plan: DO NOT OBTAIN

Taxonomy:
Two subspecies: *S. m. martinsi* and *S. m. ochraceus* Hershkovitz, 1966.
Previously considered to be subspecies of *S. bicolor* (see Hershkovitz,
1977)*.* Rylands et al. (2000) and Groves (2001)) place *S. martinsi*
as a separate species, with the two subspecies.

Habitat & Distribution:
Forests between the rios Uatumã and Nhamundá (*S. m. ochraceus*)
and rios Nhamundá and Erepecurú (*S. m.martinsi*), north of the Rio
Amazonas in Brazil.

Morphology:
Bare, black face. Bare areas. Upper surface a streaky mixture of buff,
olivaceous, and brown with forequarters more dilute or faded than
hindquarters.

Reproduction:
No specific information available at this time.

Diet:
No specific information available at this time.

Behaviour:
No specific information available at this time.

Martin's bare-face
tamarin
*Saguinus martinsi
martinsi*

Ochraceous bare-face
tamarin
*Saguinus martinsi
ochraceus*
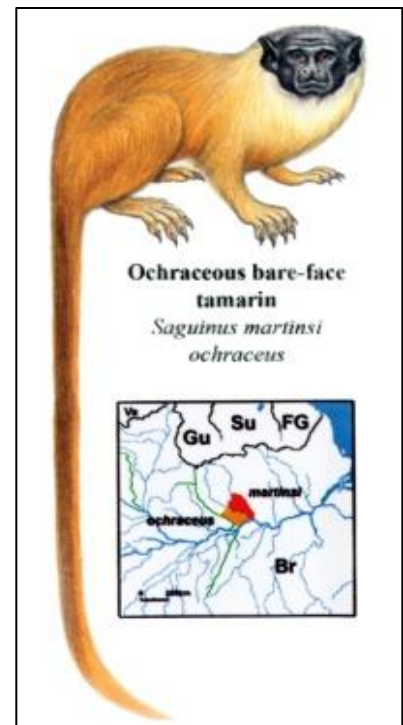
Saguinus melanoleucus (Miranda Ribeiro, 1912)

Common name:
White saddle-back tamarin

IUCN Red List: Least Concern (LC)
                          S. m. crandalli Data Deficient (DD)
CITES: Appendix 2
Regional Collection Plan: MONITORING by the TAG

Taxonomy:
Saguinus fuscicollis melanoleucus and *S. f. crandalli* of Hershkovitz (1977) were listed as subspecies of *S. melanoleucus* by Coimbra-Filho (1990) and Groves (2001, 2005). Tagliaro et al. (2005) used data on ND1 mitochondrial DNA from one specimen of *melanoleucus* and six specimens of *S. f. weddelli* to test this hypothesis. Differences between *melanoleucus* and *weddelli* were no larger than among the *weddelli* specimens, thus failing to support Coimbra-Filho's (1990) separation.

Habitat & Distribution:
Primary, secondary and lowland forest and seasonally flooded white river forest (*várzea*) east of the upper Rio Juruá, south from the mouth of the Rio Eirú, to the left bank of the Rio Tarauacá in Brazil and Peru.

Morphology:
See *Saguinus fuscicollis.*

Reproduction:
Weaning of infants occurs at 3 months. Sexual maturity occurs at about 15 months. Gestation is 145–152 days. Females give birth to their first offspring at 18 months and other births may occur at 6–12 months intervals.

Diet:
Wet season: fruit, sap, petioles. Dry season: nectar, fruit, sap, animal prey.

Behaviour:
See *Saguinus fuscicollis.*

White saddle-back
tamarin
*Saguinus melanoleucus
melanoleucus*

Crandall's saddle-back
tamarin
*Saguinus melanoleucus
crandalli*
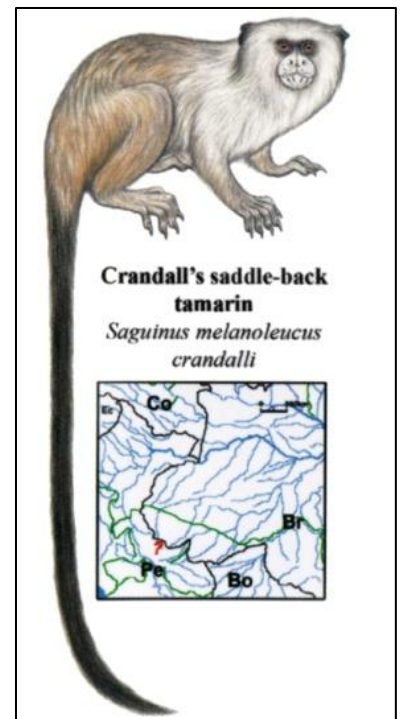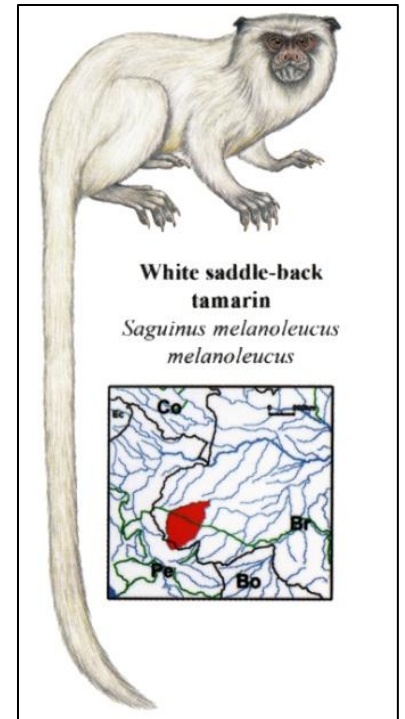
Saguinus midas (Linnaeus, 1758)

Common names:
Golden-handed tamarin
Red-handed tamarin

IUCN Red List: Least Concern (LC)
CITES: Appendix 2
Regional Collection Plan: ESB

Taxonomy:
Hershkovitz recognized two subspecies: *S. m. midas* (golden-handed tamarin)
and *S. m. niger* (black-handed tamarin)*.* Rylands et al. (2000) and Groves
(2001) regard these forms as separate species. Vallinoto et al. (2006) found
that samples from *S. midas* from the Río Uatumã separated out from those
from the Rio Trombetas to the east, about 200 km. This indicates a possibility
that red-handed and yellow-handed forms of *S. midas* may be geographical
races or distinct species (J. de Sousa e Silva Jr, pers. comm., April 2007).

Habitat & Distribution:
They live in primary and secondary forests, edges, swamps, and forest patches
in savannas, preferring open high canopy. They occur north of the Rio
Amazonas, east of the rios Negro and Branco north to Guyana, east of the River Essequibo. Brazil, French
Guiana, Suriname, and Guyana.

Morphology:
They grow up to an average of 240 mm with a tail length of 392 mm and weigh between 432 and 586 g.

Reproduction:
Weaning of infants occurs at 2–3 months. They reach sexual maturity at 15 months. Oestrous cycle lasts
around 23 days and gestation 140–168 days*.* They give birth to their first offspring (usually two) at the age of
24 months, and breed at 8.5 month intervals. Offspring are born in spring and summer and males do most of
the infant carrying. These tamarins have been observed to mate from within a few hours of giving birth and
two days after, mating being preceded by mock fighting and tonguing.

Diet:
Golden-handed tamarins feed on fruit, seed, insects and animal prey.

Behaviour:
Average group size is 5 individuals, varying between 2 and 12. Locomotion is quadrupedal. They prefer large
branches and can leap up to 8 metres. The breeding female dominates the group, not being threatened by
males. They scent mark before and after mating and during threat displays. The most common vocalization is
"pi-pi-pi". This species associates with *Mico argentatus* in the small area where their ranges overlap*.*

Saguinus mystax (Spix, 1823)

Common names:
Spix's moustached tamarin
Red-capped moustached tamarin
White-rumped moustached tamarin

IUCN Red List: Least Concern (LC)
CITES: Appendix 2
Regional Collection Plan: MONITORING by the TAG

Taxonomy:
Three subspecies: *S. m. mystax*, *S. m. pileatus* (I. Geoffroy and Deville, 1848) and *S. m. pluto* (Lönnberg, 1926). Groves (2001) considered the form *pileatus* to be distinct and listed it as a full species. This is problematic, however, because it would appear that *pileatus* separates the geographic ranges of the other two forms. This being so, recognition of *pileatus* as a full species would demand that the nominate form and *pluto* should also be considered full species. A better understanding of the geographic distributions of these moustached tamarins is needed.

Spix's mustached tamarin
Saguinus mystax mystax

Habitat & Distribution:
Forests in the Brazilian and Peruvian Amazon. They occur south of the Río Amazonas–Solimões, from the Rio Tefé and middle Juruá, west to the ríos Ucayali and Tapiche (*S. m. mystax*); west of the Rio Coarí to the Rio Tefé, south to the Rio Pauiní or Rio Mamoria (*S. m. pileatus*); and between the lower rios Purus and Coarí, south to the Rio Tapauá (*S. m. pluto*).

Morphology:
Moustached tamarins have a black head and a white moustache. The tail is black and the back and hind legs are brown. Males have unpigmented genitals. They grow up to around 258 mm with a tail length of 386 mm and weigh between 491 and 643 g.

White-rump mustached tamarin
Saguinus mystax pluto

Reproduction:
There is no information regarding age of weaning, birth interval, or age at first birth. They reach sexual maturity at 15–18 months of age. Gestation lasts 140–150 days.
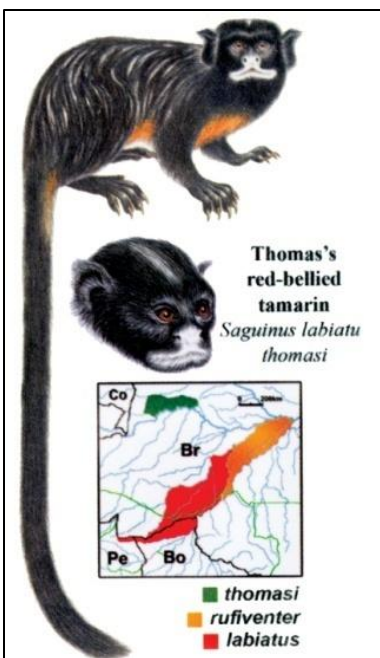
Diet:
Fruit, insects and exudates.

Red-cap mustached tamarin
Saguinus mystax pileatus

Behaviour:
They spend most time during the day foraging for mobile prey (insects). Group size is usually about 5 individuals, varying between 2 and 16. Locomotion is quadrupedal. These animals associate with *S. fuscicollis* but use higher levels of the forest, foraging for insects at 15m. As well as scent marking the substrate directly, scent marking may be performed by urinating on to the hands. Individuals reportedly may rub their cheeks in the urine of sexual partners. Vocalizations include trill calls, whistles and chirps.
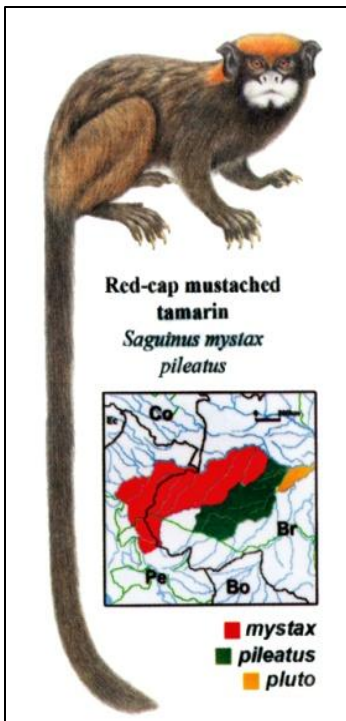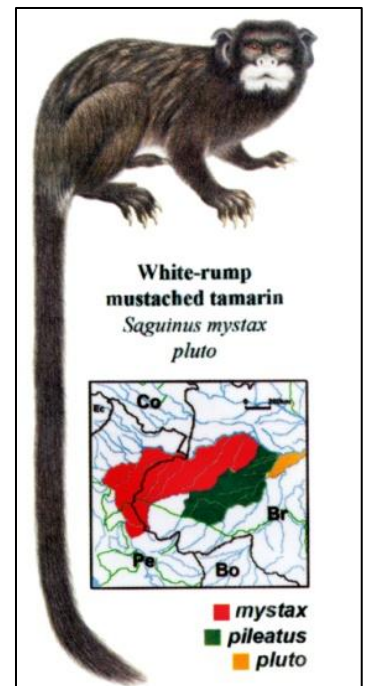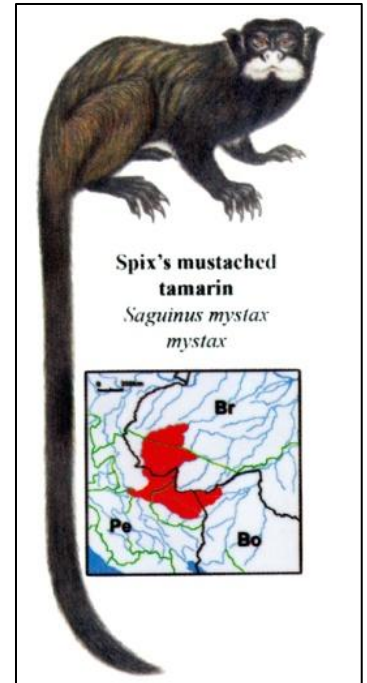
Saguinus niger (É. Geoffroy, 1803)

Common name:
Black-handed tamarin

IUCN Red List:	Vulnerable (VU)
CITES:	Appendix 2
Regional Collection Plan:	DO NOT OBTAIN

Taxonomy:
Hershkovitz (1977) considered this form to be a subspecies of *S. midas*. Vallinoto et al. (2006) indicated that the Rio Tocantins may act as a barrier to gene flow for *Saguinus niger*. This was presaged in a molecular genetic analysis by Tagliaro et al. (2005). The form described as *Mystax ursulus umbratus* Thomas, 1922, from Cametá, Rio Tocantins, Pará, listed by Groves (2001, 2005) as a junior synonym of *S. niger*, and by Hershkovitz (1977) as a junior synonym of *S. midas niger*, may in this case be considered a distinct geographical race or species (J. de Sousa e Silva Jr, pers.comm., April 2007).

Habitat & Distribution:
The largely destroyed forests of the eastern Amazon in the south of the state of Pará, Brazil, south of the Rio Amazonas, east of the Rio Xingú and Rio Fresco to the interfluvium of the rios Itapecuru and Mearim.

Morphology:
General coloration black. Middle and lower back striated with grey, buff or orange hairs. Similar to *Saguinus midas*, but upper surfaces of hands and feet black (orange or yellow in *S. midas*)

Reproduction:
No specific information available at this time.

Diet:
No specific information available at this time.

Behaviour:
No specific information available at this time.
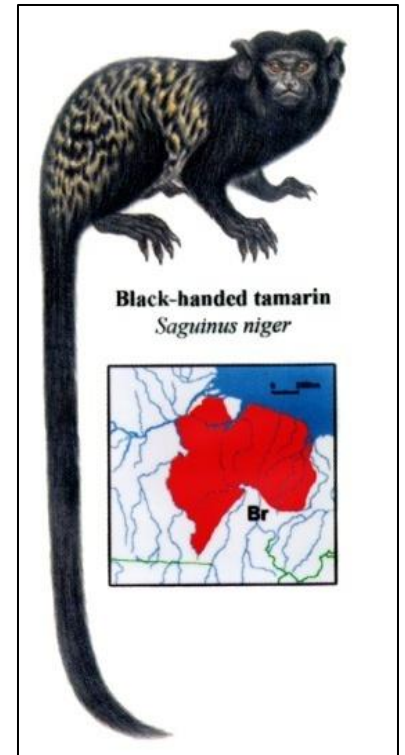
Saguinus nigricollis (Spix, 1823)

Common names:
Graells' black-mantled tamarin
Hernández-Camacho's black-mantled tamarin
Spix's black-mantled tamarin

IUCN Red List:	Least Concern (LC)
	S. n. graellsi Near Threatened (NT)
CITES:	Appendix 2
Regional Collection Plan:	MONITORING by the TAG

Taxonomy:
Three subspecies: *S. n. nigricollis*, *S. n. graellsi* (Jiménez de la Espada, 1870) and *S. n. hernandezi* Hershkovitz, 1982. Rylands et al. (2000) indicated that *graellsi* should be regarded as a separate species as Hernández-Camacho and Cooper (1976) suspected it was sympatric with a population of *S. n. nigricollis.* Groves (2001) listed it as species for this reason. Defler (2004) argued, however, that *nigricollis* and *graellsi* are not sympatric, and so we continue to list the latter as a subspecies.

Habitat & Distribution:
Primary and secondary high moist and dry tropical forests and edges up to 914 m in Brazil, Colombia, Peru, and Ecuador. According to our current (poor) understanding of their ranges, they can be found between the rios Solimões–Amazonas/Napo and Içá–Putumayo (western range limit not exactly known) (*S. n. nigricollis*), south from upper Río Caquetá through extreme northern Peru and Ecuador, to the upper Rios Pastaza and Tigre (*S. n. graellsi*), and between the ríos Caquetá, Caguan, and Orteguaza and the base of the Cordillera Oriental to Río Guayabero (*S. n. hernandezi*).
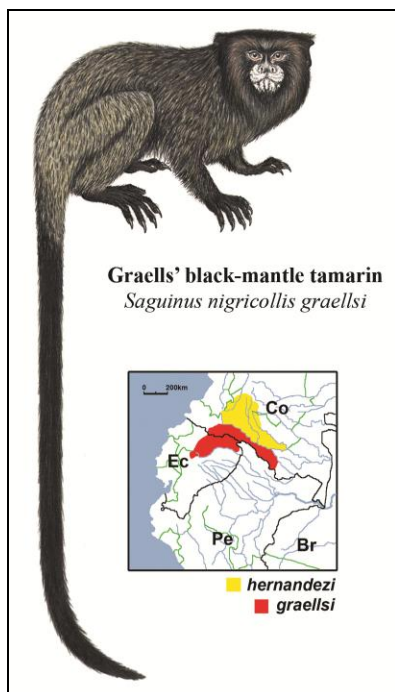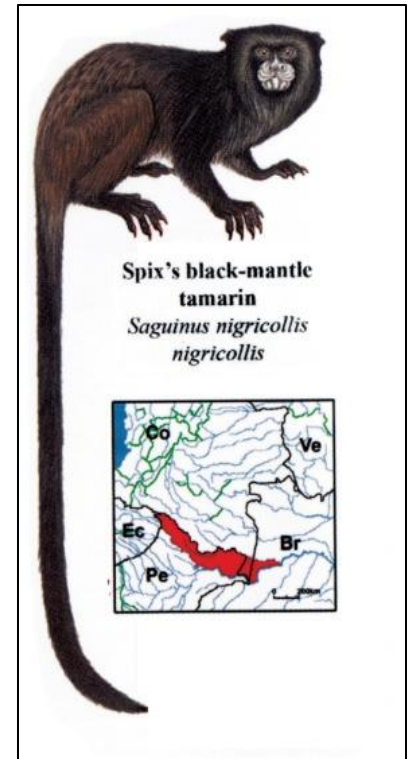
Morphology:
These animals get their name from the black mantle, which reaches to the midback and, occasionally, beyond. They have hairless ears and grey/white hair around the muzzle. The rest of the body varies from red/brown to olivaceous. They grow up to 220–226 mm with a tail length of 356–361 mm and weigh around 470–480 g.

Reproduction:
Weaning of infants occurs at 2.8 months. There is no information on sexual maturity, oestrous cycle, gestation or age at first birth. In large groups a dominance hierarchy has been reported.

Diet:
Fruit, seeds, animal prey, flowers, gums and resins. Flying insects are caught with the mouth. Large insects are caught with hands, such as large grasshoppers, which they eat head first.

Behaviour:

This species is reported to be the only tamarin to form large, noisy groups, which last only for short periods and number up to 40 individuals. Average group size is 6.3 individuals, varying between 4 and 12. Groups may merge and forage together for 1.5 day. White-throated toucans (*Ramphastos tucanus*) follow these tamarins when they are foraging. They use the chest and genital regions to scent mark branches and each other's backs.

They use vine tangles as sleeping sites.

Hernández-Camacho's
black-mantle
tamarin
*Saguinus nigricollis
hernandezi*

■ hernandezi
■ graellsi
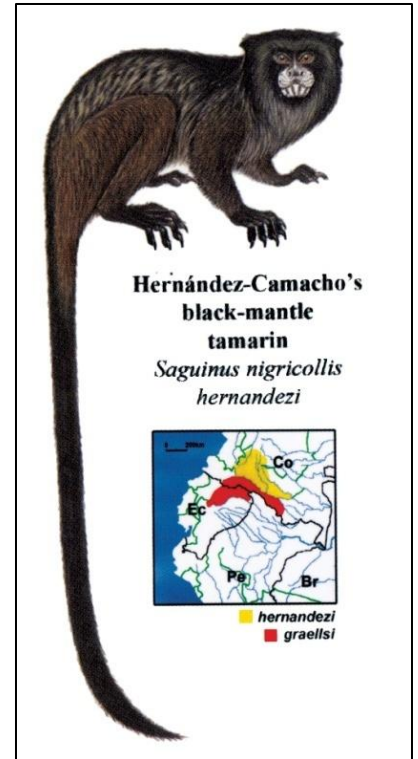
Saguinus oedipus (Linnaeus, 1758)

Common name:
Cotton-top tamarin

IUCN Red List: Critically Endangered (CR)
CITES: Appendix 1
Regional Collection Plan: EEP

Cotton-top tamarin
Saguinus oedipus

Taxonomy:
Hershkovitz (1977) considered *Saguinus geoffroyi* to be a subspecies of *S. oedipus*. Comparative morphological studies by Hanihara and Natori (1987), Moore and Cheverud (1992) and Skinner (1991) argued for them being separate species (Rylands, 1993). Groves (2001, 2005) listed *S. geoffroyi* and *S. oedipus* as separate species.

Habitat & Distribution:
Secondary wet and dry forest and low vine tangles, from sea level to 1500 m, in the north-west forest region of Colombia, between the Río Atrato and the lower ríos Cauca and Magdalena, and in the northeast Choco, east of the Río Atrato.

Morphology:
They have a long, white, fan-like crest at the top of their grey head. Their back is brown and the half tail is red. Underparts, limbs and feet are white. They grow up to 232 mm with a tail length of 372 mm and weigh between 411 and 430 g. Often considerably bigger in captivity.

Reproduction:
These animals reach sexual maturity at about 18–24 months. Oestrous cycle lasts 23 days. Gestation is one of the longest for a tamarin at around 183 days. Post-partum oestrus occurs about 10 days after birth.

Diet:
Fruit, seeds, gum, animal prey (insects, mice and birds).

Behaviour:
Group size is usually around 7 individuals, varying between 3 and 13. *Saguinus oedipus* stand bipedally to display aggression and dominance. Females scent mark more often than males. Vocal repertoire is highly complex and includes a submission squeal, an alarm trill and a high-pitched whistle for aerial predators. Infants have a play vocalization. High tree forks and vine tangles are used as sleeping sites.
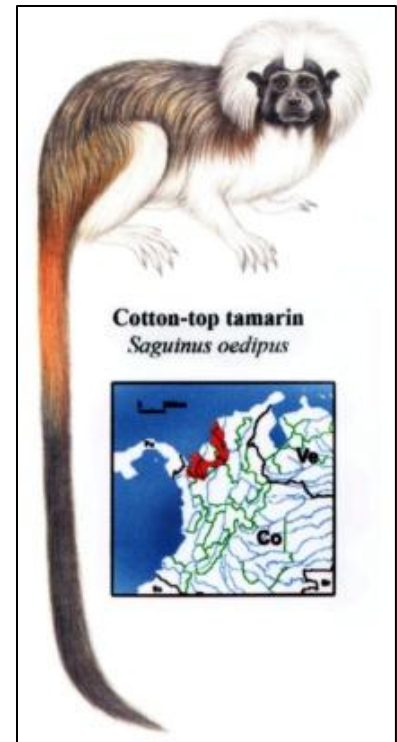
Saguinus tripartitus (Milne-Edwards, 1878)

Common name:
Golden-mantled saddle-back tamarin

IUCN Red List: Near Threatened (NT)
CITES: Appendix 2
Regional Collection Plan: DO NOT OBTAIN

Taxonomy:
Hershkovitz (1977) listed *Saguinus tripartitus* as a subspecies of *S. fuscicollis.* Thorington (1988) argued for its species status (see also Albuja, 1994). It was listed as a species by Rylands et al. (1993) and Groves (2001, 2005), but a re-evaluation of the evidence for its distribution indicates that both Hershkovitz (1977) and Thorington (1988) were incorrect (Rylands et al., in prep.), and any sympatry between *S. f. lagonotus* and *S. tripartitus* has yet to be confirmed.

Habitat & Distribution:
Lowland evergreen forest, between the ríos Curaray and Napo in Peru, west to the basins of the ríos Yasuní and Nashiño in Ecuador.

Morphology:
These animals have a black head, golden shoulders and a variegated grey, white or orange back. The underparts are orange and the tail is black above with orange below. They grow up to 218–240 mm with a tail length of 316–341 mm. There is no information on weight.

Reproduction:
No data available on life history or social structure.

Diet:
Fruit, insects.

Behaviour:
Sizes of 14 groups observed on the Rio Aushir, Peru, ranged from 4 to 8, with a mean of 5.3. No field studies had been published up to 1995**.**

Golden-mantle
saddle-back tamarin
Saguinus tripartitus

SECTION 2 – MANAGEMENT IN ZOOS

Authors:

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*Section 2.2 (Feeding): Christoph **Schwitzer**[18], Kristin **Leus**[11] , Luc **Lorca**[14], Morgane **Byrne**[3], and Melissa **Yaxley**[21]*

*Section 2.3 (Social Structure and Behaviour): Hannah M **Buchanan-Smith**[2] and J Bryan **Carroll**[4]*

*Section 2.4 (Breeding) : J Bryan **Carroll**[4], Yedra **Feltrer**[6], Peter **Galbusera**[7], Warner **Jens**[10], Kristin **Leus**[11] , Stewart **Muir**[15], Tai **Strike**[19] and Dominic **Wormell**[20]*

*Section 2.5 (Environmental Enrichment) : Agustin **Lopez Goya**[13], Warner **Jens**[10] and Dominic **Wormell**[20]*

*Section 2.6 (Capture, Handling and Transport): Eric **Bairrao Ruivo**[1], Tine **Griede**[8], Pierre **Grothmann**[9] and Dominic **Wormell**[20]*

*Section 2.7 (Veterinary : Considerations for Health and Welfare): Pierre **Grothmann**[9] and Thierry **Petit**[16]*

*Section 2.8 (Special issue) : J Bryan **Carroll**[4], Dominic **Wormell**[20]*

*Section 2.9 (Recommended (and planned) ex situ Research) : Peter **Galbusera**[7], Tine **Griede**[8]*

2.1   Housing and exhibition of the Callitrichidae

As with all captive animals, when considering the housing requirements of the Callitrichidae it must be remembered that not only is the quantity of space important, but also the quality of the space. In general terms an enclosure should provide a safe and secure environment so animals are not stressed at any time. As well as meeting the basic requirements for life in captivity, one should look at the natural history of the species in question when designing a captive habitat. The form and structural configuration of the exhibit should mimic the complex habitat of these animals in the wild taking into consideration how the animals use their habitat and their behaviours in that environment e.g. predator avoidance, sleeping behaviour, locomotion, etc. Callitrichids tend to inhabit primary and secondary rainforest habitat, living in several strata of the forest from canopy to just a few metres above the forest floor. Several of the species have even been observed descending to the forest floor periodically to forage for insects among the leaf litter. Knowledge such as this can help zoos design appropriate enclosures and night quarters for their animals. The recommendations below are based on experiences at Apenheul Primate Park and Durrell Wildlife Conservation Trust and other collections with long-standing experience of keeping callitrichids in captivity. In general the enclosure should provide a safe and secure environment so the animals are not under stress at any time.

2.1.1   Enclosure size

Access outdoors, even if for a limited time or in off exhibit areas, is beneficial to the animals, providing them with fresh air and natural sunlight. Some combination of indoor and outdoor holding/exhibit areas is,

therefore, recommended. Since most callitrichids are about the same size, enclosures can often be interchangeable for many of the different species. Recommendations for enclosure size depend on several variables such as number of months/year and number of hours/day the animals can go outside. Enclosures should be a minimum height of 2.5 metres, and the combined indoor/outdoor area accessible to the animal 80% of their waking hours year round should be 22.5 cubic metres. Indoor enclosures should also have a minimum total floor size of 3 sq. metres, a height of 2.5 metres and be configured into at least two separable areas to enable easier cleaning and to hold new animals for introduction, for parturition or if unwell. Outdoor enclosures should be a minimum of 10 sq. metres, with a minimum height of 2.5 metres. For large family groups (>5) more room should be provided. Depending on the number of hours that the animals are inside or outside and the relative sizes of these enclosures, some adaptation to these recommendations is possible. Due to their small size, *Cebuella pygmaea* enclosures may be slightly smaller depending on group size. For some species or groups it may be necessary to provide off-show accommodation so that the animals can retreat from the public.

2.1.2   Door and tunnel design

All animal doors and tunnels should be placed high (minimum 1.5–2m) above the substrate as it is unnatural for callitrichids to travel close to the ground. At least two doors (10 cm. square) between each enclosure/holding facility should be constructed. They should be spaced wide enough apart to prevent dominant animals from controlling passage between enclosures. Doors should be able to be easily controlled by keepers from outside the cage either via slides or cable systems.

To conserve heat and prevent drafts in the inside areas flaps can be added to the animal access doors. Several zoos now use soft perspex/pvc material as the draft excluder. This sits on an angled door frame and is easily lifted up by the tamarins and marmosets as they move in and out (see drawing and photo hereunder from Apenheul Primate Park).
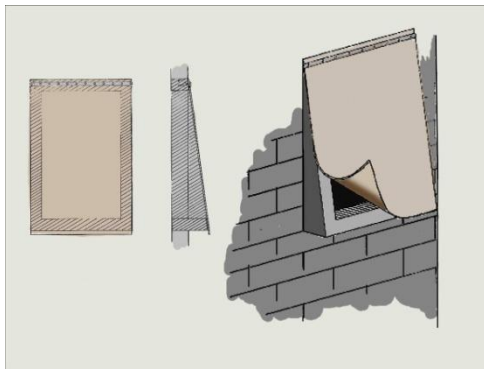
Keeper doors should be large enough for easy entry, although entry into cages should be minimized to prevent stress to the animals. To assist with this, facilities should be designed to allow for keeper access to the nest boxes from outside the enclosure and feeding the animals without walking in the enclosure. By positioning the food and water receptacles at the front of the enclosure (see picture hereunder at Apeldoorn), a simple lifting plexiglass panel allows for placement or removal of food and water bowls.

Unless they are within an enclosed area such as an animal house, keeper doors should have a safety porch attached to avoid escapes when a keeper is working in with the animals.

Tunnels can be used to connect adjoining units or to link inside and outside enclosures. This provides an opportunity to build in a temporary holding area between two slides. It is possible to design this section to be removable as a capture and transfer tool (see section on Handling). It is also possible to use this tunnel system to hold animals and read transponders.

Feeding station arrangements at Apenheul

2.1.3 Construction materials

Indoor exhibits for callitrichids should be made of non-toxic materials impervious to the weather, which allow for proper control of temperature, humidity and ventilation. While in the past many holding facilities were made of materials designed for ease of cleaning, recent knowledge of the importance of olfactory cues used by tamarins and marmosets has changed management practices and reduced the need for intensive cleaning protocols. Pest prevention and control is important to prevent possible predation or spread of disease, so solid materials such as concrete, cement, brick, certain types of plastic or solid wood are recommended.

Outdoor exhibits should, if possible, also be predator and pest proof and appropriate shelters should be provided in case of inclement weather. Provisions should be made for areas with direct sunlight and areas with shade. Cleaning is less of an issue as most will have natural substrates and natural climatic conditions will help maintain standards of hygiene. Minimizing access by vermin is also advisable in the outside area by the appropriate selection of materials.

2.1.4 Barriers

Typical barriers for primate exhibits are of five main types: Solid walls, glass walls, wire mesh, electric fencing or water. Some of these barriers fit certain terrain, climates, thematic goals and budgets better than others.

Walls are relatively low cost, easy to construct (except on slopes) and provide shade and wind barriers. For callitrichids they can be constructed of wood, concrete or cement and can be disguised by coating them with artificial rockwork.

Glass is used as a barrier primarily at public viewing areas, and is generally used in conjunction with other materials (walls and wire) for containment. Benefits of glass are the ability for up close viewing, prevention of disease transmission and public feeding. Some of the drawbacks include high expense, reflection problems, and keeping the glass clean. Glass should be made opaque (rubbing soap on outside of enclosure, draping outside of enclosure with plastic or fabric) when animals are introduced to a new exhibit.

The use of **wire mesh** fencing or nylon netting as a barrier for callitrichids greatly increases the amount of usable surface area of an exhibit, providing much additional climbing space. It can also help when monitoring animal health, pregnant animals and in sex determination of young. It is an inexpensive and secure form of containment, but care must be taken to bury the mesh approximately 1 metre below the substrate to prevent predators such as foxes from digging under the fencing. Alternative to this is anchoring the fencing securely to a solid foundation. Regular maintenance of the mesh and protection from the elements (including the use of a safe paint) is important. The netting or fencing should be tightly strung with tension to prevent animals from becoming entangled in loose netting. Care also must be taken to use the proper gauge mesh to prevent young infants from being able to climb through or get their heads stuck in the mesh. Depending on the species this should be between 2 and 4 sq cm. One disadvantage of mesh enclosures is the necessity of the public to view the animals through mesh. With wire being a permeable barrier, safety and health factors of the callitrichids and visitors can also be of concern. A stand-off barrier preventing visitors from close proximity to the monkeys will help reduce the likelihood of disease transmission between the public and the animals.

Electrified fencing has been used successfully with callitrichids but must be used with care as the shock could be dangerous or fatal, especially for young animals. It is only advisable for use with very large enclosures. Occasionally it is used as a secondary barrier behind a primary barrier to keep out predators. For free-roaming callitrichids a monkey-proof perimeter barrier is also needed.

The use of **water** moats provides an unobstructed eye-level view for the visitor, permitting barriers to be less evident to the visitor, and can help immerse the visitor in the landscape of the animal. Moats are generally more expensive than walls or fencing, although, depending on local legislation, can be made fairly inexpensively using plastic pond liner for water containment. For callitrichids a depth of 0.4 metre is sufficient. Potential drawbacks are drowning, freezing of moats in winter (although callitrichids should not be kept outside in freezing weather) and increased viewing distance. The slope of the moat should be gentle (<30 degrees) on the animals' side to prevent animals from accidentally slipping into the moat. Branches can be provided at the water's edge as escape routes in case an animal falls in. Moat barriers also increase the needed space for the exhibit, with moat width for callitrichids being recommended at minimum of 4 metres (depending upon plantings on and around the enclosure). If using water as a barrier, additional cover or shelters should be provided to avoid airborne predation by birds of prey. Note that some callitrichids, especially *Leontopithecus chrysomelas* have been known to swim water barriers.

Visitor barriers – It is recommended that all callitrichid enclosures have a stand-off barrier for visitors to prevent them having direct contact with the animals. This is primarily to prevent possible health problems being transferred to the animals, e.g. herpes, but it also prevents feeding and it may also reduce stress levels.

2.1.5   Orientation and location of enclosures

Exhibits and holding enclosures should be orientated so that different groups of the same species are not within visual contact with each other. Visual contact can lead to increased levels of stress over territoriality, mate preference, etc. Visual barriers can be planted or hung outdoors to prevent visual contact. The use of solid walls between adjacent cages indoors can also solve this problem. Auditory barriers are

helpful, as too much external noise can stress animals and prevent communication within the group. Strategic placement of plants within and between enclosures can help soften the aural environment and provide shade during the summer, especially important in hot climates. It is important that outside enclosures are open to sunlight especially in northern regions to allow the animals to sit in the sun during parts of the day.

There is some concern about housing callitrichids in tropical houses with large waterfalls in the same area. Vocalizations are a crucial form of communication for callitrichids and waterfalls can prevent these communications being heard by members of the group. It is also considered to be a possible hazard purely because of the impact of this background noise.

2.1.6 Cleaning and substrates

In general a substrate of natural materials such as wood bark, wood shavings, wood wool (excelsior) or mulch inside, and soil or grass outside is recommended. Woodwool should initially be used with care as some animals unfamiliar with it can become entangled in it. A recent innovation in substrate for callitrichids is the use of a "biofloor", a thick covering of woodchips (25 cm) under which lays a filterpad, with a concrete floor and drain below the pad. The biofloor functions as a biological system to prevent build-up of pathogens or parasite infestation. Urine drains through the biofloor and out through the drain, while faeces are spot-cleaned. The biofloor requires total replacement every 3–4 years. More information on the biofloor system is available from Apenheul Primate Park. As mentioned earlier, callitrichids will frequently search through substrate for insects or pieces of food. A soft substrate will also decrease the possibility of injury to animals due to falls. The substrate for interior enclosures should cover an impervious floor with a drain. It should be able to be spot cleaned fairly frequently (2–3 times/week), and the entire substrate removed for intensive cleaning periodically (1–2 times/year) or in the event of the detection of disease pathogens / parasites. Most external substrates will be cleaned naturally via sunlight, rain, decay, etc. At least one interior cage should be maintained with the ability to remove substrate easily, in case an animal must be closely monitored for diarrhoea, etc. or for biological sample collection.

In callitrichids, scent marking is an important behaviour so cleaning regimes need to consider this. Cleaning cage fittings in rotation is one way to avoid causing stress to the animals if all their territory is sterilised at one time.

2.1.7 Furniture

Permanent – At least one nest box of wood should be provided indoors for each family group, even if not used for sleeping. These boxes should be a minimum of 25 x 25 x 25 cm and made of wood, and can double as capture boxes if fitted with appropriate slide doors. Doors should be approximately 10 cm square to allow access and egress by an adult with infants riding on its back. The access hole should have a slide which can be operated from outside the cage to allow easier capture of animals. The nest boxes should be placed high up in the enclosure. If groups grow large (more than 4 individuals) a second nest box is recommended, although even large families often prefer to use only one nest box. Shelves or beams adequate for resting on should be provided at various heights along the walls of the enclosures. Ideally the nest boxes should be removable from the keeper corridor without the keeper needing to enter the animal exhibit.

Temporary – In addition to the permanent furnishings, natural materials such as tree branches, potted plants and ropes should be included in the enclosures to stimulate natural behaviour and to provide a variety of substrates for locomotion. For callitrichids the diameter should be appropriate to the animals' hand and foot anatomy (i.e. smaller for pygmy marmosets, etc.) with diameters between 1 and 3 cm. Larger branches or

tree trunk pieces with natural bark, such as oak, can also be included. When placed horizontally these provide ideal resting places where animals can stretch out. The temporary furnishings should provide physical flexibility to the environment, simulating the softness and lack of rigidity of the animals' natural habitats. Flexible materials such as branches, ropes, and ladders (with rungs spaced appropriately) will promote exploratory and locomotor behaviour, stimulate muscle tone and balance, as well as providing shelter, cover and visual barriers for animals. Remember that callitrichids will use vertical as well as horizontal perching to move around the enclosures. Exhibits and holding facilities should be designed to allow for flexibility, with thought given to multiple attachment points for ropes, etc. throughout the enclosures. Temporary furnishings also allow the changing of the configuration and structure of the animals' habitat, simulating the ever-changing habitats in nature. Temporary furnishings made of absorbent materials will also be used by the callitrichids for scent marking. Complete cleaning and/or removal of all such temporary furnishings should not be carried out. It should be done piecemeal in sequential stages. Major cleaning (with water and soaps) is necessary only once or twice per year. The changing of temporary furnishings will also help the animals to develop behavioural flexibility and to learn strategies to cope with changing pathways and navigation throughout their habitat. See Section 2.3 (Enrichment) for further information.

Planting – Obviously all plants available to the animals should be checked for toxicity before being placed in the enclosure. Live plants are desirable as they promote many of the behaviours described above including gum feeding, provide perches and pathways through the environment, can harbour insects, provide cover and shade and will grow and change with time. The British and Irish Zoo Federation Plant Group has developed a data base of plants suitable for zoo enclosures. A list of toxic and safe plants is included below.

Table 2.1.7-1:List of plants that are reported to be safe or toxic for primates (Tine Griede, 1989)

SAFE PLANTS LIST FOR PRIMATES		
Anise Hyssop	Bamboo (various species)	Banana
Beans (green, pole, etc.)	Blue-Leaf Wattle	Borage
Broccoli (entire plant)	Bromeliads	Brussels sprouts
Cantaloupe	Casablanca	Cast Iron Plants
Chive Blossoms	Clover	Comfrey
Corn	Cottage Pinks	Cup-of-Gold Vine
Daisies	Dandelions	Day Lilly
Dianthus	Double Canterberry Bells	Elm
Fig (various species)	Ginger	Glorious Glean Trailing Mix
Hackberry	Hibiscus	Hollyhocks
Honey Locusts	Honeysuckle	Horseradish
Johnny Jump-ups	Kablouna Calendulas	Long-lived Magnolias
Lemon Basil	Lemon Gem Marigold	Lemongrass
Malabar Spinach	Mammoth Sunflower	Masturtion
Melons	Nasturtiums (India-Alaska)	Palm Trees
Pansies	Passion Vine	Peas
Peppermint	Pine	Pumpkin
Roses (Flowers rich Vit. C)	Rubber Tree	Semi-Dwarf Delphinium
Snow-white Delphinium	Shellginger	Silverberry
Southern Dewberry	Strawberry	Sweet Potato
Sydney Golden Wattle	Tangerine Gem	Thyme
Turnips	Violets (flowers)	Weeping Chinese Banyan
Whirlybird Nasturtiums	Willow	Wild Cherry Tree

TOXIC PLANTS LIST FOR PRIMATES		
Acorn (Oak)	Akee Fruit	Amaryllis
Anemonee	Angel Trumpet Tree	Apricot (kernels – leaves)
Arrowhead	Autumn Crocus	Avocado (leaves)
Azalea	Baneberry	Belladonna
Betel Nut Palm	Bird of Paradise	Bittersweet
Black Locust	Bleeding Heart	Boxwood
Bracken Fern	Buckeye	Burning Bush
Butter Cup	Caladium	Calla Lily
Castor Bean	Cedar	Century Plant
Cherries (pits)	Chinaberry	Choke Cherry
Christmas Rose	Chrysanthemums	Climbing Nightshade
Cocklebur	Columbine	Cowbane
Cyclamen	Daffodil	Deadly Nightshade
Delphinium	Desert Potato	Devil's Ivy
Dieffenbachia	Dogwood	Dumbcane
Dutchman's	Breeches	Elderberry
Elephant Ear	English Ivy	Euonymus
Fava Bean	Flags	Four O'clock
Foxglove	Goldenchain	Hemlock
Holly Berries	Horse Chestnut	Horsetail Reed
Huckleberry	Hyacinth	Hydrangea
Impatiens Plant	Indian Turnip	Inkberry
Iris	Ivy	jack-in-the-pulpit
Japanese Tallow	Japanese Yew	Jasmine
Jequirty Bean	Jerusalem Cherry	Jimson Weed Seeds
Johnson Grass	Jonquil	Lantana
Larkspur	Laurel	Linustrum
Lilly of the Valley	Lobelia	Locoweed
Lucky Nut	Lupine (Blue Bonnet)	Marsh Marigold
May Apple	Milk Weeds	Mistletoe Berries
Mock Orange	Monkshood	Moonseed
Morning Glory	Mother-in-law	Mountain Laurel
Mulberries	Mushrooms / Toadstools	Narcissus
Nightshade	Oak Tree	Oleander
Peach (seeds)	Pencil Tree	Peony
Periwinkle	Peyote	Philodendron
Pigeonberry	Pinks	Poinsettia
Poison Hemlock	Poison Ivy	Pokeweed Berries
Potato (green parts)	Primrose	Privet
Rananculus	Rhododendron	Rhubarb Leaves
Rosary Pea	Snow Drop	Sorrel
Star of Bethlehem	Sweet Pea	Swiss Cheese Plant
Thorn Apple	Threadleaf	Tobacco
Tomato (green parts)	Tulip Bulb	Virginia Creeper
Water Hemlock	Wild Black Cherry	Wild Mustard
Wisteria	Yaupon Tree	Yellow Jessamine
Yew Berries		

Feeding and watering sites – Ideally at least two feeding and watering sites should be available within the enclosures to ensure dominant animals are not preventing subordinate animals getting access to food and water. They should be placed in areas of easy access for all animals, at least 1.5 metres off of the ground. Ideally perches or shelves should be built adjacent to these sites to allow relaxed consumption of food. Food is usually presented in trays or bowls and water can be presented using "Lixit" devices, water bottles or in bowls. Water bottles hung from wire should be regularly checked for blockage or leakage. Care must be taken not to place food and water sites below perches or other areas that could lead to contamination with faeces or urine. The design of feeding and watering places should allow for removal of trays or bowls for cleaning or filling without the keeper needing to enter the enclosure.

2.1.8 Lighting and photoperiod

Both the amount and quality of light, and the photoperiod (timing of light exposure throughout the day and year) are very important for callitrichids in captivity. In the wild some callitrichids experience different levels of light depending upon the strata they inhabit and the time of year.   There is evidence that lengthening and shortening of daylight times throughout the year can trigger physiological changes related to reproduction. Artificial light can be used to simulate tropical day length changes, especially in temperate latitudes far from the tropics. The average number of daylight hours should be 12 hours with minimal light (if any) used at night. Consideration needs to be given to the use of ultra violet light in inside areas.

Windows and or skylights should always be provided for the animals. Natural sunlight is very important for the animals and lack of it can promote physiological changes related to reproduction, vitamin D synthesis and even the intensity of coat colour in lion tamarins. Skylights and windows should be UV penetrable if possible. Allowing the animals to monitor the outside environment through windows can also lead to a reduction in stress by providing the animals more choice within their environment. Windows can also serve as enrichment providing changing visual stimulation. Care must be taken that window placement also allows the animals privacy from curious members of the public and disturbances from maintenance, construction, and other activities.

2.1.9 Temperature and humidity

Most zoos keep their indoor callitrichid enclosures at a minimum of 18 ^{o}C with no resultant problems, although some may maintain temperatures up to 24 ^{o}C. In Apenheul during colder months when animals are still going outside, the temperature is maintained at 20 ^{o}C inside so the difference between inside and outside will be less. Others maintain at slightly higher temperatures, up to 24 ^{o}C. A basking spot should be provided (under a heat lamp or a heated shelf) where animals can go to warm up. This is less important during warmer weather but vital when the temperature outside is below 16 ^{o}C. Recommended heating systems include heat lamps, radiators or central heating. Care must be taken not to place any hot pipes or heating equipment within reach of the animals. Air conditioning or mist systems are used sporadically in some countries where temperatures reach very high levels (>32 ^{o}C).

Most zoos with outside enclosures permit their callitrichids free choice to go outside down to 5 ^{o}C. Depending on the type of barriers (glass, wire or water) and weather conditions some zoos will give the animals free choice down to freezing point. Consideration can be given to providing a heat lamp outside.

Inside humidity should be kept at a minimum of 60% to promote good skin and coat condition. Humidity can be raised by placement of humidifiers in service areas, use of misters or simply placing pans of water near heating elements. Humidity and temperature should be monitored daily.

A ventilation system that ensures a CO_2 level below 0.1% everywhere in the enclosure should be installed. Indoor enclosures should have a full air circulation system with air inflow points positioned in the upper part of the enclosure building and air outflow points in the lowest parts.

2.1.10 Free-range enclosures

Several species of the Callitrichidae have successfully been maintained in a free-ranging situation in the zoo, i.e. where there is no barrier between the animals and the public. Several factors, however, must be taken into account, such as the species-typical group composition. All male or all female groups, or groups where one of the parents has died, may follow their natural instinct and try to leave the area in an attempt to find a partner. Because of the typically strong cohesion within a callitrichid family, it is not advisable to separate one or more animals and keep them inside to ensure the rest of the group will remain in the neighbourhood. By doing so there is a danger that group stability will suffer and the group structure will fall apart.

Contact with visitors must be avoided. When the free-ranging area is large and interesting with enough possibilities for the animals to withdraw, callitrichids tend to keep a safe distance from visitors. A no-feeding regulation is essential to maintain this safe distance. Individuals who are hand-reared or animals which are emotionally attached to people (former pets, etc.) can cause problems and can easily change the attitude of the group towards people.

Release procedure **–** When releasing the animals for the first time into a strange environment, there is a chance that the animals, being unrestricted by any barrier, may panic and run off, and subsequently not be able to find their way back. It is advisable, therefore, initially to place a temporary cage inside the future free-roaming area connected via a tunnel to the animal door from the holding area. This cage can be very small (0.5 m^3 is sufficient.) but it must be furnished with wood. The animals may then be given access to this cage so they have the opportunity to scan the environment and scent mark the cage, entrance and furnishings. After three to five days this cage can be removed except for the furniture which then serves as a recognition point. The outdoor slide must be easily accessible, preferably by more then one route.

2.2   Feeding

2.2.1   Basic diet: food components and feeding regime

In most facilities, marmosets and tamarins are fed a mixture of a complete feed (either "homemade" or commercial pellets and/or jellies), produce (a variety of fruit and vegetables) and some form of animal protein (insects, egg etc.).

Produce

In the wild, marmosets and tamarins feed on a wide variety of fruits. Offering fruit and vegetables in captivity allows for presenting the animals with this important dietary variation. It must however be remembered that commercial fruits and vegetables are generally higher in easily digestible carbohydrates and lower in fibre, protein and calcium than wild fruits (Oftedal and Allen, 1996; Schwitzer et al., in press). From the selection of food items offered, the animals will not always make a choice based on their nutritional requirements, but they can be expected to make a selection based on sugar content, fat content or novelty (Price, 1992). It has repeatedly been found that marmosets and tamarins in captivity have a preference for fruit and insects above vegetables and the nutritionally complete feed (e.g. Price, 1992; Power, 1992). While,

for at least a number of institutions, the supply of live invertebrates is somewhat limited so that overfeeding on insects may be expected to be less of a problem, fruit and vegetables are usually readily available. Therefore, if surplus amounts of produce are fed so that the animals can meet their energy requirements on this, they may end up with an imbalanced diet deficient in vitamins, minerals and protein (Power, 1992; Oftedal and Allen, 1996).

For this reason, it has been recommended to:

1) not feed more than 30% of the total energy <u>intake</u> in produce (remember that this can be substantially smaller than 30% of the energy <u>offered</u>!) (Power, 1992);
2) try to achieve an <u>intake</u> of not more than 30% of dry matter in produce (Oftedal and Allen, 1996);
3) feed marmosets and tamarins two or more times a day, offering the nutritionally complete feed in the morning when animals are most hungry, and most produce later in the day (Power, 1992; Oftedal and Allen, 1996).

Animal products

All marmosets and tamarins consume significant amounts of animal food, and especially insects. Insects are good sources of protein and lipids, but a poor source of calcium and some other minerals. In addition, a large proportion of the time budget of the animals in the wild is taken up by foraging for invertebrates, and attempting to mimic this foraging behaviour can be an important source of environmental enrichment (see section 2.2.4). Invertebrates (preferable live ones) should therefore be offered to all marmosets and tamarins. These can be mealworms, crickets, grasshoppers etc. Apart from invertebrates, other sources of animal products can also be used (see example diets in appendix A–E). The feeding of baby mice is not encouraged – and forbidden by the IRMC (International Recovery and Management Committee) for lion tamarins because of the risk of infection with callitrichid hepatitis virus (Golden Lion Tamarin Management Committee, 1996) (also see Veterinary guidelines).

Complete feeds

Insects are generally low in calcium and have low calcium:phosphorus ratios (Oftedal and Allen, 1996; Allen and Oftedal, 1996). Commercial fruits and vegetables are low in fibre, protein and calcium. In order to prevent nutritional deficiencies as a consequence of feeding commercial produce and insects, and in order to meet the specific nutrient requirements of callitrichids (see section 2.2.2), it is important to offer the animals a complete feed, which can either be homemade or can be a commercial marmoset and tamarin pellet or jelly. The calcium content of invertebrate species offered can also be raised by feeding these a calcium-rich diet before they are offered to the monkeys (Ullrey, 1986; Crissey et al., 1999).

Gum

As indicated in chapter 1.6, for *Cebuella pygmaea*, *Callithrix jacchus* and *C. penicillata*, and to a lesser extent the other marmosets, gum is an essential part of their diet in the wild, particularly at times when other food items are scarce. Offering a replacement for wild exudates such as gum arabic (see section 2.2.4) to these species in captivity may not be a nutritional necessity as long as all necessary nutrients are present in sufficient amounts in the other portions of the diet. It may however be considered a behavioural necessity, and the biochemical digestive challenges it presents to the gut may well be important. Some institutions even feel that the inclusion of gum in the diet may help to combat Marmoset Wasting Disease, although firm data to back this up are still lacking. To other callitrichid species, gum arabic can also be offered every now and then by way of

nutritional variety and behavioural enrichment. During a gum digestibility study, Power and Oftedal (1996) offered gum arabic powder at a level of 9% of the dry matter of the diet. This was readily consumed by the marmosets and challenged their digestive (fermentation) abilities.

Group feeding

From the above it is obvious that it is necessary to have some idea of, and control over, the actual intake of individual animals rather than just the amounts offered. Because marmosets and tamarins live in family groups, the social structure of the group may influence the intake of an individual in this group. For example, in a study on common marmosets it was found that the breeding female consumed more of the preferred food so that the animal with the greatest nutritional demands actually consumed the most imbalanced diet (Power, 1992). For this reason, multiple food bowls should be used for groups and the quantities of produce must be monitored carefully. It is important to at least periodically monitor food intake.

2.2.2   Nutrient requirements

Energy

A number of studies have measured the mean daily metabolisable energy (ME)[*] intake for cotton-top tamarins (*S. oedipus oedipus*):

Kirkwood and Underwood (1984):	$540 \text{ kJ} * \text{kg}^{-0.75} * \text{day}^{-1}$ ($129 \text{ kcal} * \text{kg}^{-0.75} * \text{day}^{-1}$)[**]
	(321 kJ/day or 77 kcal/day for a 0.5 kg animal)
Kirkwood (1983):	$456 \text{ kJ} * \text{kg}^{-0.75} * \text{day}^{-1}$ ($109 \text{ kcal} * \text{kg}^{-0.75} * \text{day}^{-1}$)
	(271 kJ/day or 65 kcal/day for a 0.5 kg animal)
Escajadillo et al. (1981):	$542 \text{ kJ} * \text{kg}^{-3/4} * \text{day}^{-1}$ ($130 \text{ kcal} * \text{kg}^{-0.75} * \text{day}^{-1}$)
	(322 kJ/day or 77 kcal/day for a 0.5 kg animal).

By means of linear regression of ME intake of adult primates by weight, using log transformed data, Kirkwood and Underwood (1984) came up with an equation for primate inter-species mean ME requirement:

y (daily ME requirement for maintenance) = $405 \text{ kJ} \times (\text{Body weight in kg})^{0.75 \pm 0.047}$

$(97 \text{ kcal} \times (\text{Body weight in kg})^{0.75})$

Clarke et al. (1977) had earlier also calculated a primate inter-species mean ME requirement as 107 kcal/kg$^{0.75}$/day.

These figures compare well with the gross energy requirement for callitrichids reported by Morin (1980) and Barnard et al. (1988): 142–232 kcal/kg body mass/day. One has to bear in mind, however, that the amount of gross energy needed for maintenance is related to the digestibility of the diet (in other words, how much of the gross energy of the diet is digestible and metabolisable by a particular species). The apparent digestibility of gross energy in an artificial diet fed to five species of callitrichids ranged from 71 to 86% (Power,

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[*] Digestible Energy (DE) = gross energy minus energy lost in faeces. Metabolisable Energy (ME) = DE minus energy lost in urine and as methane (in case of ruminants) (McDonald et al., 1995).

[**] 1 kcal = 4.184 kJ and 0.239 kcal = 1 kJ

1991). Yaxley (2007) found a voluntary intake of 137 kcal/day and 129 kcal/day in captive *Leontopithecus chrysomelas* and *L. rosalia*, respectively, fed a normal zoo diet. Energy expenditure due to resting metabolic rate in *Callimico* was calculated as 40.1 kcal/day based on a 12 hr active/inactive cycle (Power et al., 2003). Thompson et al. (1994) estimated that the ME equivalents for dietary carbohydrate, protein and fat for golden lion tamarins (*L. rosalia*) are 4.0, 4.1 and 9.0 kcal/gram respectively.

The studies on energy intake in cotton-top tamarins indicated that the energy intake of adults generally decreased with age and that, although energy intake did not markedly rise during pregnancy, the energy intake of females appeared to double during lactation in the weeks 3–6 post partum (Kirkwood and Underwood, 1984).

Protein

Commercial feeds for some New World primates such as cebids, callitrichids and *Callimico* tend to be high in protein (>20% on a dry matter basis) because New World primates have been said to have higher protein requirements than Old World monkeys (NRC, 1978). This is probably a result of the fact that in some studies, callitrichids on high protein diets were observed to "thrive better" (Kirkwood, 1983; Kirkwood et al., 1983; Flurer and Zucker, 1985; Barnard et al., 1988). In fact, protein deficiency has been discussed as a possible cause of "wasting marmoset syndrome" (Flurer and Zucker, 1985; Barnard et al., 1988).

However, recent research has not supported higher protein requirements of New World primates. For *S. fuscicollis*, 2.8g protein (from casein)/kg body weight/day (7.3% of dietary dry matter) was shown to be sufficient (Flurer and Zucker, 1988). Protein requirements (from soy protein concentrate) for maintenance of nitrogen balance in adult common marmosets were 6.6% of dietary dry matter or 2.5 g/kg body weight/day (Flurer and Zucker, 1988). Yaxley (2007) found that captive lion tamarins *Leontopithecus chrysomelas* and *L. rosalia* had a crude protein intake of 13.6% and 9.6% of dietary dry matter (4.76 g/day and 3.35 g/day), respectively. The animals were in apparent good health, and the *L. chrysomelas* were breeding successfully. It was noted, however, that the animals were foraging for ants, caterpillars and flies in addition to their provisioned diet, which were not accounted for in the study and may well have increased protein intake (Yaxley, 2007). Tardif et al. (1998) did not find any differences in growth and reproduction between common marmosets fed purified diets containing 15% or 25% protein (as fractions of estimated dietary ME concentration). The minimal protein requirement for maintenance of common marmosets was estimated to be 6% of the diet (Flurer et al., 1988). The animals started to eat their faeces if the protein level in the diet dropped below this value, or if the diet was lacking in the essential amino acids histidine and/or arginine (Flurer and Zucker, 1988). Estimated adequate concentrations of protein for post-weaning growth and reproduction of nonhuman primates range from 15 to 22% in the dry matter of diets containing conventional feed ingredients (NRC, 2003). Protein quality greatly affects the required concentration.

Crissey et al. (1999) noted that an increased level of dietary protein should not be deleterious to healthy animals. High protein commercial products may in fact help to dilute the effect of low protein commercial produce often offered in zoos (Oftedal and Allen, 1996). However, excess dietary protein may increase urinary calcium loss and thus dietary calcium requirements (NRC, 2003).

Vitamin D

Vitamin D plays an important role in the homeostatic control of calcium and phosphorus levels in the circulation, in the absorption of dietary calcium and in various, not yet completely understood, aspects of cell metabolism (Allen and Oftedal, 1996; Power et al., 1997). Sufficient amounts of Vitamin D are therefore

essential for the normal growth and development of bone as well as the maintenance of mature bone tissue (Power et al., 1997). The condition whereby the bones of young, growing Vitamin D-deficient animals become soft and pliable is known as "rickets". The softening of bone in adult animals with Vitamin D deficiency is called "osteomalacia" (Allen and Oftedal, 1996).

Vitamin D occurs in two main forms, vitamin D_2 (ergocalciferol) and vitamin D_3 (cholecalciferol). Vitamin D_2 is formed in injured or dead plant parts through irradiation. Vitamin D_3 is formed in the skin of most vertebrates (including primates) after irradiation by ultraviolet light of wavelengths of 290–315nm, or UV-B (Allen and Oftedal, 1996; Power et al., 1997). In contrast to Old World primates, most New World monkeys appear much less capable of efficiently utilizing the plant form of vitamin D (Vitamin D_2) and must therefore rely on a sufficient supply of D_3, either formed in the skin or provided in the diet (Oftedal and Allen, 1996; Power et al., 1997).

Most glass excludes light of wavelengths below 330nm (Ullrey, 1986). Most captive primates therefore often have no, or insufficient, exposure to natural UV-B light, in which case vitamin D_3 either has to be provided through the diet and/or the animals must be exposed to artificial sources of UV-B light. Because there may be significant inter-species variation in the efficiency with which dietary vitamin D_3 is utilised, it is probably safer to also ensure adequate exposure to UV-B light (Power et al., 1997). By way of example, the Golden Lion Tamarin Management Committee (1996) recommends, for animals with insufficient access to natural UV-B light, between 30 and 60 minutes of exposure to artificial UV-B light (290–315nm). The lights should be hung 1 to 2 m above favoured resting places such as branches or nest-boxes, but not within reach of the animals! Please make sure always to follow the instructions of the manufacturers. Depending on the climate and housing, extra UV-B exposure may only be necessary in winter.

Most New World monkeys appear to be tolerant of high (toxic to most other animals) doses of dietary vitamin D_3. This is hypothesized to be due to a low binding affinity of their vitamin D receptors in target organs, which may place captive New World monkeys at a higher risk of developing vitamin D deficiency than other monkeys (Takahashi et al., 1985; Power et al., 1997). NRC (2003) estimates of requirements in purified diets are 2,400 IU vitamin D_3/kg dry matter. Estimated adequate concentrations in diets containing conventional feed ingredients for post-weaning nonhuman primates are 2,500 IU/kg dry matter, acknowledging that there are anecdotal reports of higher requirements for callitrichids under certain circumstances (NRC, 2003; see also Crissey et al., 2003).

Power et al. (1997) found that serum values of 25-OH-D of 50–120ng/ml appeared to be normal values for wild *S. oedipus*. Because studies on *C. jacchus* indicated a high probability of acute bone disease in animals with serum values below 20ng/ml, and because callitrichids appear to be relatively resistant to Vitamin D toxicity, Power and colleagues concluded that until further studies are conducted it is probably safer to consider 50ng/ml as the lower limit for 25-OH-D serum concentrations. Below this level, the possibility of vitamin D_3 deficiency should be considered. Pregnant female cotton-top tamarins had lower serum values, suggesting a higher turnover of vitamin D, and a higher requirement for vitamin D, during pregnancy. Juvenile *S. oedipus* also had higher serum values than did adults.

Vitamin E (adopted from Crissey et al., 2003)

Callitrichid requirements for vitamin E have been studied only in the common marmoset. To support normal plasma α-tocopherol concentrations and inhibit hydrogen peroxide-induced haemolysis, 4 to 48 mg of D-α-tocopherol/kg of purified diet were required (McIntosh et al., 1987). When fish oils were added to a purified diet, requirements increased to over 95 mg of D-α-tocopherol/kg (Ghebremeskel et al., 1991). Young

common marmosets had normal plasma α-tocopherol concentrations on 130 IU or less of α-tocopherol/kg of purified diet (Charnock et al., 1992). The NRC (2003) estimated that the requirement for vitamin E in a purified diet is in the range of >95–130 mg all-*rac*-α-tocopheryl acetate/kg dry matter. The estimated adequate vitamin E concentration in diets containing conventional feed ingredients was set at 100 mg all-*rac*-α-tocopheryl acetate/kg dry matter.

Vitamin C

Like other simian primates studied, *Callithrix jacchus* and *Saguinus fuscicollis* were found to be unable to synthesize ascorbic acid or vitamin C (Flurer and Zucker, 1989). It is likely that vitamin C is an essential nutrient to all callitrichids.

Because Vitamin C in extruded monkey biscuits usually deteriorates rapidly and because canned primate food does not contain vitamin C, fruits, vegetables and browse tend to be important sources of vitamin C in primate diets (Allen and Oftedal, 1996). Vegetables of the cabbage family, citrus fruits, rose hips and some types of browse are good sources of vitamin C (Allen and Oftedal, 1996).

The miminum vitamin C requirement for adult *C. jacchus* was found to be 15mg/kg metabolic weight (a diet with 500 ppm), which is much higher than that for humans (4mg/kg metabolic weight). However, the requirement of *S. fuscicollis* was much higher again than that of *C. jacchus* (requiring a diet with more than 2000 ppm) (Flurer and Zucker, 1989). There may therefore be considerable variation among callitrichid species. Luckily, Vitamin C is generally considered to be one of the least toxic vitamins. Indeed, in order to assure that adequate levels reach the animals, very high levels of vitamin C are often added to manufactured foods because of the instability of ascorbic acid (Allen and Oftedal, 1996). The NRC (2003) recommends 200 mg vitamin C/kg of dietary dry matter for post-weaning non-human primates (as a source, ascorbyl-2-polyphosphate is recommended).

Calcium

The wild diet of many callitrichids is essentially a mixture of fruits, invertebrates and exudates. Both fruit and invertebrates tend to be poor sources of calcium (unless the insects offered in captivity have been fed a high calcium diet). However, a number of gums contain significant amounts of calcium and may therefore be an important source of this nutrient, especially for wild marmosets.

Generally speaking, calcium requirements of mammals are about 0.5–0.8% of dry matter for growth and lactation (Allen and Oftedal, 1996). Considering the high reproductive output of the Callitrichidae, an adequate and reliable calcium supply is likely to be important for these animals. Indeed, *C. jacchus* in captivity have been shown to be able to distinguish between plain water and a calcium lactate solution. They drank more of the calcium solution and reproductive females (pregnant and/or lactating) had the highest intakes (Power et al., 1999).   Because an imbalance in the calcium: phosphorus ratio can lead to poor absorption of both minerals, the Ca:P balance in the diet should preferably be between 1:1 and 2:1 (Allen and Oftedal, 1996). Ca and P concentrations of 0.8% and 0.6% of dietary dry matter, respectively, are recommended by the NRC (2003) for post-weaning non-human primates on diets containing conventional feed ingredients. The NRC (2003) notes that much of the phytate phosphorus found in soybean meal and some cereals appears to be of limited bioavailability.

In captivity, excessive feeding of fruits, seeds or grains, muscle meats and insects can have severe diluting effects (Allen and Oftedal, 1996). On the other hand, if these items are fed as part of a well balanced

diet (see section on diet composition below), calcium deficiency is less of a concern. For example, the 130 g diet (as fed) of a 500 g tamarin could safely contain 3–5 grams of insects without diluting the overall calcium content of the diet (Oftedal and Allen, 1996).

Iron

Mammals only require trace amounts of iron, and iron deficiency is rare in healthy animals receiving solid food (Allen and Oftedal, 1996). The mammalian body normally regulates iron balance by controlling iron absorption, as it lacks effective means to excrete iron (Allen and Oftedal, 1996). Dietary excess of iron may be one of the significant causes of haemosiderosis and/or haemochromatosis in many captive wild animals, including marmosets and tamarins (Gottdenker et al., 1998). Gottdenker et al. (1998) investigated the livers of 232 callitrichids that died at the Bronx Zoo between 1978 and 1997. Of these, 94.4% had some degree of haemosiderin deposition within the hepatocytes and/or mesenchymal tissue, and 82.3% had moderate to severe scoring. The fact that the haemosiderin deposition was predominantly intrahepatocytic, that there was a zonal gradient of hepatic haemosiderin, and that sinusoidal haemosiderin deposition increased with age, strongly suggested that the haemosiderosis in the callitrichids at the Bronx Zoo was primarily due to enteric iron absorption. The iron content of the diets of the Bronx marmosets (191.2–238.2 mg/kg) and tamarins (191.9–305.6 mg/kg) was higher than the 100 mg/kg dry matter NRC (2003) recommendation. The NRC (2003) provides the following note with their recommendation: "Because some primates appear to be susceptible to iron-storage disease, particularly in the absence of iron-binding polyphenols found in some plants and when large quantities of fruits are offered, it might be desirable to limit dietary iron concentrations to near or slightly below this concentration. However, this is difficult because of the iron associated with use of calcium phosphates (produced from rock phosphate) as a phosphorus source. Calcium phosphates produced from bone (as a byproduct of gelatine manufacture) are lower in iron. In either case, iron in the phosphate source is thought to be lower in bioavailability than iron in ferrous sulfate, as long as the intake of fruits and their associated citrate and ascorbate contents (which promote iron absorption) is limited."

Iodine (adopted from Crissey et al., 2003)

Iodine deficiency has been observed in common marmosets fed a diet composed of natural ingredients and containing 0.03 mg I/g of dry matter (Mano et al., 1985). Plasma thyroxine concentrations declined and plasma thyroid-stimulating hormone concentrations increased. Thyroid glands were hypertrophied and hyperplastic. Cerebral brain-stem cell size was reduced in offspring from second pregnancies. These signs were prevented by providing 0.65 mg I/g of DM. Lower supplemental levels of iodine were not tested. Estimated adequate iodine concentrations in diets containing conventional feed ingredients are 0.35 mg/kg DM (NRC, 2003).

Other minerals

In the wild, moustached tamarins (*Saguinus mystax*) were observed to feed on surface soil and soil from the broken mound of leaf cutting ants. Analyses of soil samples suggested that the most likely hypothesis for the function of soil feeding in these animals was that it serves as mineral supplementation (Heymann and Hartmann, 1991).

2.2.3   Diet recommendations

Amount of food per day

An average active adult animal will consume a total of about 5% of body weight per day on a dry matter basis, or about 16 to 24% of body weight on an as fed basis (Crissey et al., 1999, 2003). For lactating animals this can be 1.5 times the usual intake, and callitrichid females may be almost continuously pregnant and/or lactating. As an example, adult golden-headed lion tamarins and golden lion tamarins in an intake trial carried out at Colchester Zoo by Yaxley (2007) showed a voluntary intake of 39.4 and 26.2 g dry matter per day, respectively, when fed on a normal zoo diet.

All of this of course implies knowing fairly accurately the body weights of the animals involved. This is not only important for monitoring amounts of food to be offered and consumed, but also helps to detect disease at an early stage. (See also section 2.2.1 on group feeding.)

Diet composition (abridged from Crissey et al., 2003)

Callitrichids should be fed at least twice per day. The interval between morning and afternoon feeding should be between 4 ½ and 6 ½ hours. More food should be provided in the morning (or more active period) than in the afternoon (less active period), though the same food categories should be offered. Since marmosets spend much of their time in the wild foraging, food might be offered at multiple times throughout the day, and the food scattered to promote foraging.

When consumed in its entirety, the diet should contain the nutrient concentrations presented in Table 2.2.3-1 (dry matter basis).

Table 2.2.3-1: Estimated adequate nutrient concentrations (dry matter basis) in diets containing conventional feed ingredients intended for post-weaning callitrichids, accounting for potential differences in nutrient bioavailabilities and adverse nutrient interactions, but not accounting for potential losses in feed processing and storage (original Table from NRC, 2003; adapted from Crissey et al., 2003).

Nutrient	Concentration	Nutrient	Concentration
Crude protein, %	15-22[a]	I, mg/kg	0.35
Essential n-3 fatty acids, %	0.5[b]	Se, mg/kg	0.3
Essential n-6 fatty acids, %	2[c]	Trivalent Cr, mg/kg	0.2
Neutral detergent fiber (NDF), %	10[d]	Vitamin A, IU/kg	8,000
Acid detergent fiber (ADF), %	5[d]	Vitamin D_3, IU/kg	2,500[g]
Ca, %	0.8	Vitamin E, mg/kg	100[h]
Total P, %	0.6[e]	Vitamin K, mg/kg	0.5[i]
Non-phytate P, %	0.4	Thiamin, mg/kg	3.0
Mg, %	0.08	Riboflavin, mg/kg	4.0
K, %	0.4	Pantothenic acid, mg/kg	12.0
Na, %	0.2	Available niacin, mg/kg	25.0[j]
Cl, %	0.2	Vitamin B_6, mg/kg	4.0
Fe, mg/kg	100[f]	Biotin, mg/kg	0.2
Cu, mg/kg	20	Folacin, mg/kg	4.0
Mn, mg/kg	20	Vitamin B_{12}, mg/kg	0.03
Zn, mg/kg	100		

[a]Requirements for growth of young and for lactation are best met by the higher concentrations in this range. Required protein concentrations are markedly affected by amounts and proportions of essential amino acids. Taurine may be a dietary essential through the first postnatal year.

[b]Requirement can be met by a-linolenic acid. Required concentration may be lower when supplied by eicosapentaenoic or docosahexaenoic acids.

[c]Requirement can be met by linoleic or arachidonic acids.

[d]Although not nutrients, NDF and ADF at or near indicated concentrations appear to be positively related to gastrointestinal health.

[e]Some of P in soybean meal and certain cereals is bound in phytate and poorly available.

[f]Iron-storage disease (hemosiderosis) is a potential problem, particularly when large quantities of fruits are offered, presumably because citrate or ascorbate promote iron absorption. Under these circumstances, it may be important to limit iron to near or slightly below this concentration. Particular attention should be given to iron concentrations in phosphorus and calcium supplements and to selection of sources that are low in this contaminant.

[g]There are anecdotal reports of higher vitamin D_3 requirements under some circumstances, perhaps related to impaired absorption in individuals with colitis.

[h]As all-*rac*-α-tocopheryl acetate.

[i]As phylloquinone.

[j]Niacin in corn, grain sorghum, wheat, barley, and their byproducts is poorly available unless they have undergone fermentation or wet-milling.

[k]Ascorbyl-2-polyphosphate is a vitamin C source that is biologically available and quite stable during feed processing and storage.

It is assumed that insects fed will normally be crickets or mealworms. As mealworms contain substantially more fat and energy than crickets, if an animal is overweight, a higher percentage of crickets to mealworms should be used. Insects should be fed an appropriately fortified 8% calcium diet 24–48 hours prior to feeding them to the callitrichids.

Vegetables and starchy vegetables offered can be cooked (steamed or microwaved) to enhance digestibility. For those animals that consume gum in the wild, this should be provided, but not in addition to the diet. Fruit must be decreased by weight as gum is offered. If for logistic or cost reasons, it is felt that the use of insects should be decreased, increasing the nutritionally complete portion of the diet is appropriate (by weight).

Food items should be of a size appropriate for easy handling by individual callitrichids. Sizes and shapes can be varied for behavioural enrichment. Food sharing and stealing is common within family groups and may serve to teach the young about important food items.

Certain foods (like excessive quantities of fruit) may periodically cause diarrhoea in some animals. The manufacturer's literature for a gel diet states that loose stools may result from feeding large quantities. Reductions in the proportion of fruit or temporary restriction to a nutritionally complete primate biscuit or canned diet may clear up the problem. Use of a nutritionally complete primate diet is critical to proper dietary management of these animals, but the diet should be reassessed for nutrient content if one commercial product is substituted for another. Oral medications may be hand-fed in favourite food items. Fresh water should be available at all times. Food and water dishes should be disinfected daily to prevent bacterial build-up, especially of *Pseudomonas* spp.

Diet evaluation (adapted from Crissey et al., 2003)

Ultimately, it is the diet (food items) actually consumed that will determine nutrient status. If the diet (or certain portions of the diet) is not consumed, nutrient intakes may be inadequate. Thus, periodic assessment of diet consumption is important. Following is an example method for determining diet consumption. Data on diet offered and consumed should be collected for at least five days. Different keepers should be involved to account for variations in food preparation. Consumption is calculated by determining the quantity (by weight) of food items offered and subtracting the quantity of food remaining. Food portions should be prepared by each care-giver, according to their normal procedures. Each item should be weighed on a digital scale before placing it in the food pan. Orts (leftover food) should be collected and weighed at the end of the feeding time or before the beginning of the next feeding time. Enrichment food items should be accounted for in the same manner. Moisture concentrations of food may change from feeding to ort collection because of desiccation or from additions of water from rain or misting, and must be accounted for. Determinations of intake on a dry-matter basis can be made by using a drying oven to determine dry matter in samples of food items offered and of recovered orts. If a drying oven is not available, a food pan containing weighed food samples should be placed near, but outside, the cage where the animals are housed, in an area free of pests. The pan should be left for the same period of time as the fed diet and subjected to the same environmental conditions. The percentage water gain or loss should be determined and a correction factor calculated. This factor can then be used to determine the actual quantity of diet consumed without the conflicting problem of moisture change. A computer analysis (e.g. Zootrition™) can be used to calculate the nutrient content of the diet offered and consumed. For nutritional advice, please consult the Callitrichid TAG's nutrition advisor or the EAZA Nutrition Group.

Box 2.2.3-1: Nutritional recommendations for callitrichids in captivity

Nutritional recommendations for callitrichids in captivity

Callitrichids are diurnal, with highest activity levels seen in the morning. Due to their small body size it is recommended that the daily feed ration is divided into 2 or 3 feeds spread evenly throughout the day.

Maintenance diet: Total amount offered per individual per day should equal between 16- 24% of body weight on an as fed basis (or 5% of body weight per day on a dry matter basis). Training callitrichids to sit on scales is highly beneficial to their dietary management (see chapter 1.6 pg 6 for body weight data).

Diets should comprise of at least 50% nutritionally complete feed (e.g. commercially produced new world primate biscuits or marmoset/tamarin powdered diet). Remaining diet comprising of fruit, vegetables, animal products (see Table 2.2-2). Gum (e.g. gum arabic) must be provided 2-3 times weekly for marmosets and Goeldi's monkeys. Tamarins do not require gum but may benefit from it as enrichment.

Wild diets vary seasonally, so captive diets should be varied to provide sensory stimulation and promote naturalistic feeding/foraging behaviours. (Note that enrichment involving food should use items that are part of the daily ration and not extra food which would lead to an unbalanced diet.)

Food items should be prepared fresh (cut/chopped edge of food is prone to bacterial contamination). Food pieces should ideally be cut to approximately 1cm in size, but should vary in shape to enhance sensory stimulation.

Food and water bowls must be washed and disinfected daily to prevent bacterial build up.

Fresh water must be available at all times.

Box 2.2.3-2: Examples of foodstuffs that can be included in diets for captive callitrichids.

Examples of suitable ingredients to include:			
Fruits	**Vegetables**	**Animal products**	**Commercial feeds (gluten free)**
Apple/pear	Carrot/ parsnip (grated)	Meal worms (*Tenebrio molitor, Zophobas morio*)	New world primate biscuits (e.g. Trio munch)
Berries (e.g. blueberry, strawberry, blackcurrant)	Cooked starchy veg (e.g. potato/ sweet potato/ butternut squash/ suede)	Wax worms	Marmoset jelly
Peach/ nectarine	Broccoli	Crickets/ locusts	Tamarin cake
Apricot	Courgette	Cooked chicken	Gum arabic
Coconut	Cucumber	Egg (scrambled/ boiled)	
Tomato	Celery	Cheddar cheese	
Fig	Peas/beans		
Grapes	Pepper		
Cherry	Herbs (e.g. basil, parsley)		
Kiwi			
Melon			
Plum			

2.2.4   Method of feeding: eliciting natural foraging behaviour

Both for conservation, education and welfare purposes, it is important that callitrichids in captivity are able to perform as many of their natural behaviours as possible, including their foraging behaviours (e.g. Molzen and French, 1989).

Gums

When gum is fed in captivity, we suggest offering the gum on set places for extended periods of time, as exudate trees are often visited for extended time periods in the wild. Especially for larger groups of

Cebuella, exudates should be offered in several places in the enclosure in order for every group member to have access to this important resource.

In captivity, offering gum may not necessarily be a nutritional necessity (not if all necessary nutrients are present in sufficient amounts in the other portions of the diet), but it could be considered a behavioural necessity. *Cebuella pygmaea* and *Callithrix* species are able to truly gouge trees (see above). Offering gum in reservoirs drilled in natural branches (Kelly, 1993; Buchanan-Smith, 1998), or use of an artificial gum tree as developed by McGrew et al. (1986) may stimulate them to not just lick the gum but also to actively gouge the wood. For the other callitrichid species exudates are of a limited and more seasonal importance. These animals can be offered gum every now and then by way of nutritional variety and behavioural enrichment. Since these species tend not to gouge trees, gum may also be offered to them by smearing it along the surface of trunks and branches in the enclosure. The exudates can then be either licked up, or if solidified, picked up with teeth or hands. Some tamarins have also been observed in the wild to extract gum from crevices by sticking a hand into the source and licking the exudate from the fingers (Snowdon and Soini, 1988). When feeding on the gum of the pods of the *Piptadenia* tree, *Callimico* was observed to hang upside down by its hind feet from the branch that the stem was attached to. They then either reach the seed pods or pull them up by means of the flexible stem (Pook and Pook, 1981). Hanging up gum dispensers from the roof on a flexible rope can help mimic this behaviour. Heymann (1999) hypothesized that in species with gastrointestinal tracts that are not specially adapted to gum feeding, eating gum not long before bed time may be a strategy to lengthen the amount of time the gum remains in the gut, and therefore the time available for bacterial fermentation of the gum (see also Jersey diet for callitrichids in the appendix).

The replacement of natural exudates most often offered to callitrichids in captivity is gum arabic. Gum arabic comes from Old World *Acacia* species and is a heterogenous, complex polysaccharide. Although we cannot yet be certain that this particular gum is nutritionally similar to the great variety of others that the animals find in the wild, there is a good chance that biochemically, gum arabic presents the same digestive challenge as the gums eaten by wild callitrichids (Power, 1996). It is also the only gum that is currently easily obtainable (e.g. in powder form) from pharmacies, bakeries and suppliers of manufacturers of confectionery.

Animal prey

For *Cebuella pygmaea*, *Callithrix* sp., *Saguinus geoffroyi*, *Saguinus mystax*, *Saguinus labiatus*, *Saguinus imperator*, and possibly *Saguinus midas*, live insects distributed at random from dispensers, or tossed into the enclosure are perhaps most suited. A number of callitrichid species only infrequently forage on the floor. For these species devices that hold live invertebrates that cannot fly or hold on to branches and leaves very well (e.g. mealworms) should not be suspended such that the prey falls on the floor. They should be hung such that the prey falls on a substrate higher in the enclosure (e.g. a shelf with Astroturf). Insects such as live crickets and grasshoppers are more likely to position themselves at all levels of the enclosure (Buchanan-Smith, 1998, 1999a, 1999b).

For *Saguinus fuscicollis* (possibly also *S. nigricollis* and *S. bicolor*) as well as *Leontopithecus* sp., extractive foraging devices such as foraging boxes and baskets are most suited. These can be filled with some sort of substrate such as saw dust, turf, hay etc. mixed with mealworms or small bits of non-animal foods etc (see also Molzen and French, 1989). They can either be hung up to challenge the locomotor abilities of the animals or can be offered stationary. Both open baskets and closed devices with small holes for "blind" foraging can be used. Natural tree logs with natural or human-made crevices are equally suited. To mimic foraging in bromeliads for lion tamarins, small insects and food items in pineapple heads can be used.

Fruit

For specific site extractive foragers, small fruits or small pieces of fruit can be used in extractive foraging devices. Every now and then larger fruits such as whole apples, bananas etc can be hung from the ceiling or branches (e.g. on ropes or speared on flexible bamboo canes (Buchanan-Smith, 1998) to challenge the animals' locomotor skills. If foods are hung from pieces of string longer than the extended length of the monkey this may stimulate the "feeding while hanging upside down" behaviour (Buchanan-Smith, 1998). Take care! Not all fruit should always be offered whole because this may increase the chance of some animals monopolising favoured food items.

GOLDEN RULE FOR ENRICHMENT INVOLVING FOOD:

DO NOT USE ADDITIONAL FOOD but only use food types and quantities that are part of the daily diet of the animal.

2.2.5   Other considerations

Obesity

Several field studies of callitrichids have involved the collection of body weight measurements, but the majority of weight data were collected as parts of broader studies, and comparisons between wild and captive animals were not always made (e.g. Garber and Teaford 1986; Garber, 1991). Studies such as that of Encarnación and Heymann (1998), Savage, et al. (1993) and Araújo et al. (2000) found that captive callitrichids had higher body masses than wild conspecifics, which was considered to be a consequence of differences in diet and physical activity rather than constitutional. This provides an indication that captive animals may be at risk of becoming obese when overfed or incorrectly fed. Problems of concern in obese primates include skeletal abnormalities, heart disease, diabetes and some forms of cancer, all of which will affect an individual's welfare and longevity (Lane et al., 1999; Schwitzer and Kaumanns, 2001; Bray, 2004). Excess feeding might also lead to higher body weights of infants, which in turn may cause birth complications.   This is suspected to be the case with *S. imperator*, where 30% of all female mortality is due to dystocia and 18.2% of infants are stillborn (Mermet, 1999).

It is thus suggested, as noted in chapter 2.2.2 above, to closely monitor body weights of captive callitrichids and evaluate diets in terms of the energy content consumed by the animals. To reduce body weight of overweight/obese individuals, the overall quantity of the (nutritionally adequate) diet can be reduced, beginning with a 5% decrease (Crissey et al., 1999). When animals are put on a diet, the body weight decrease has to be carefully and tightly monitored so the animals do not lose too much weight too quickly.

Seasonality

In larger outdoor enclosures or free ranging conditions in northern climates animals may be more active in the summer than in the winter. Body weight and food intake may thus vary seasonally and should be monitored.

Periodontal disease

Animals require some harder and crunchy foods as well as soft foods in order to abrade the tarter from their teeth. Otherwise this leaves them vulnerable to dental disease (Crissey et al., 1999).

Gastrointestinal problems: colitis, allergy to wheat, soy or milk proteins and seed ingestion

Colitis is considered one of the most important life-threatening diseases in captive tamarins (Gozalo and Montoya, 1991). Chronic colitis is often associated with Wasting Marmoset Syndrome, and in *Saguinus oedipus* it is also found associated with colon cancer. Wasting Marmoset Syndrome is one of the most frustrating medical conditions encountered in callitrichids: signs include chronic, unresponsive diarrhoea, rough hair coat, and alopecia of the tail. Paralysis of the tail and hind limbs may occur in the later stages of this disease. Mortality rates among marmosets and tamarins that develop wasting are high. Colitis may be multifactorial. One suspected cause is chronic exposure to a diet-related antigen to which the tamarins are allergic, such as proteins in wheat, soy and milk (Gozalo and Montoya, 1991; Gore et al., 1999). These factors should be investigated in case of intestinal problems or symptoms of Wasting Marmoset Syndrome in animals receiving a diet with such ingredients. Most commercially available products contain some of these allergens, including many food and aroma supplements (because of their excipients, i.e. soya lecithin). Avoiding these foodstuffs complicates the choice of diet constituents, which is already restricted by the poor taste and palatability of certain feed raw materials. As more data become available, diets for captive callitrichids may also have to be reconsidered in this light.

As was indicated above, for most wild callitrichids, the indigestible bulk of the diet largely consists of seeds that are swallowed whole and are passed through the digestive tract largely unchanged (Power, 1996; Passos, 1997; Dietz et al., 1997). Many callitrichid defecations consist almost entirely of seeds (Power, 1996).

The seeds ingested are very large for the body size of the monkeys, and seed ingestion is a constant phenomenon. The hypothesis was put forward that large seeds might be important in providing mechanical stimulation of the gastrointestinal tract and that a lack of such stimulation might lead to gastrointestinal diseases (Heymann, 1992).

Other nutrition-related health problems

Nutritional deficiencies (other than Wasting Marmoset Syndrome) may present as alopecia of the tail: lack of folic acid, vitamin B or biotin are the most common examples. However, callitrichids with pancreatic worms may also develop tail alopecia. It may also occur as a result of overgrooming or excessive scent marking. Some important viruses are brought to callitrichids through food and environment. Rats and mice are the hosts for one of them, the lymphocytic choriomeningitis: when affected, marmosets show anaemia and hepatitis. This pathology may occur when callitrichids have access to rodents or their excretions. Of course callitrichids should never be fed on mice.

2.2.6   *Example diets from experienced institutions*

Because for many of the nutrients, exact requirements for callitrichids are not known, because in many European institutions homemade products rather than commercial feeds are used, and because learning from practical experience is important, it may be helpful to include a number of diets as they are used at this moment in institutions with a long and successful history of callitrichid housing and breeding. We have thus included the diets used for various callitrichid species in five different institutions. They are listed as they were submitted to us, and we have not verified the validity of the nutrient and energy analyses shown. The responsibility for the correctness of these analyses is with the submitting institutions. The five diet examples may in parts differ from the recommendations given in the text above, which is due to different institutions relying on different recipes and traditions.

ZOO D'ASSON

supplied by: Morgane Byrne and Luc Lorca

Asson Zoo had already implemented a gluten-free diet for the zoo's tamarins and marmosets before August 2007. Nevertheless, the latter were still subject to chronic diarrhoea and were highly sensitive to entero-pathogens: pastries and candies offered by the visitors, in spite of warnings and prohibitions, seemed to figure as causal or at least aggravating factors. Despite therapeutic treatments attempted on the outbreak of enteritis and Wasting Marmoset Syndrome (WMS) for individual or multiple members of the collection, the state of the animals in question became chronic and their wasting, which could last weeks or months, inevitably led to their loss. Therefore the diet set up in the zoo since 2007 excludes any food potentially containing tannins, intolerance factors (lactose, gluten), or allergens (seeds, nuts, soya, milk proteins (casein), soya lecithin and lactose, and thus a great majority of industrial products and artificial aromas, as well as many food supplements because of their excipients. The new diet was accompanied, from the very start of food transition (August 2007), by the disappearance of digestive disorders in Asson's collection of callitrichids.

This diet takes current data concerning the nutritional needs and the feeding habits of callitrichids into account. The porridge used is the base of the hypoallergenic mode presented here: it ensures the contribution of 60% of energy and 30% of proteins of the daily ration. We also ensured that certain nutrients would not be presented in excess in order to avoid toxicity (vitamins A, C, D and E, as well as certain minerals). In addition to this complete porridge, callitrichids receive fruit and vegetables daily, a protein snack (egg, insects, meat, etc.) in the course of the day, and hypoallergenic feline diet (containing hydrolysed proteins, but no soya protein) at nightfall to cater for stress and nocturnal fluctuations of temperature. Lastly, a probiotic/prebiotic/enzyme complex was added to the porridge every Sunday, the day with most visitors, and therefore of pastry, candies, and ice-cream offering.

After a 20-month follow-up of this new hypoallergenic food plan, with no observed side effects (although that remains still short term), a new food transition made it possible to replace the home-made porridge by an industrial one developed thanks to the results obtained. It is a complete low-allergen foodstuff intended for new world monkeys (the *Saimiri* model was used to adapt the formula of this new food), which is also intended for callitrichids when associated with a marmoset food complement produced in parallel by the same supplier. Its composition participates in colon flora balance, thus improving the role of the intestinal mucous membrane barrier with respect to pathogenic germs, and regulating colon fermentation. It stimulates the intestine's local immunity, and its high content in soluble and insoluble fibre controls intestinal transit time and cleans the intestine.

Seeing that before August 2007, Asson Zoo was already using a gluten-free diet, but was still confronted with WMS and other digestive disorders, this new diet highlights that certain species of callitrichids are sensitive to other allergens: if the diet in place from now on in Asson excludes the most probable, these primates are undoubtedly not sensitive to all: the next step is to examine which of these allergens is(are) the root cause(s). In the meantime, a ration stripped of the most common allergens, and not only gluten, seems to be the best solution.

Asson diet without gluten, arachnid, cheese, soya, lacto and casei :

(For one callitrichid per day: (% of fresh ingredients))

– Commercial allergen-free new world monkey diet [a] (reconstituted to 75% moisture)	48.5
– Commercial feline diet with hydrolysed proteins (but no soya proteins)	11.5
– Commercial marmoset complement [b]	0.6
– Fruits	27.0
– Vegetables	3.4
– Starchy vegetables	3.0
– Insects/meat	6.5

Daily diet for one callitrichid in Asson: 87g fresh weight:

– 09h00:   – Porridge [c]
                            – Orniflor (once a week on Sunday)
– 10h00:   – Fruits (4 pieces (each one = 6 g) from different fruits)
                            – Vegetables (1 piece (6 g))
– 1500: Snack (proteins): 6 g (twice weekly=insects; other days=cooked chicken, fish, omelette, shrimp)
r 1700–1800: commercial feline diet: 10 g for the evening/night.

- Once weekly: prebiotic-probiotic-ferment complex (Orniflor liquid) is added to the porridge (every Sunday morning). On Sundays there are lots of visitors often feeding cookies, bread, ice-cream and other allergen-full food despite the feeding ban.
- *Fruits: banana, apple, orange, melon, pear, kiwi, peach, watermelon, apricot…*
- *Vegetables: cooked carrots, cooked potatoes, raw cucumber, raw endive…*

[a] Commercial allergen-free new world monkey diet (Monkey Mash powder). This product uses low-allergen ingredients. This is a powdered product formulated to be mixed with water and heated to porridge.**Ingredients**: *sunflower cake, egg powder, starch of corn, Arabic gum, banana, Colza oil, Psyllium, pollen, Malto-dextrin, lactic ferments, MOS, beta-glucans, vitamins and minerals, Lysine.* **Composition**: Metabolisable energy: 3415 kcal/kg or 14274,7kJ/kg, Crude protein : 20%, Carbohydrates : 32%, Crude fat : 9,7%, Crude fibre: 3%, Ash : 13%, Moisture : 10%, Ca/P=2,6, Calcium =1,44%, Sodium = 0,4%, Potassium=0,9%, Phosphorus =0,55%, Vitamin D3=4420 UI/kg, Vitamin C=400mg/kg.

[b] Commercial marmoset complement (powder): Callitrichid complement with *banana and Malto-dextrin, witch contains* Ca, Mg, Mn, vit D3, vit E and vit C

[c] Porridge is composed of 10g powder + 0,5g Callitrichid complement + 3–3.5 water equivalent volumes (30–35 ml) = 42g/callitrichid

Mulhouse Zoo

supplied by: David Gomis and Pierre Moisson

Daily diet for Callitrichids

- *Feeding schedule:*

  07h30   "Tamarin gruel" (*ad libitum*)
  11h30   Fruits (excluding bananas) and vegetables + 1 or 2 protein sources (see Table below) + "Tamarin powder"
  17h30   Fruits (including bananas) and vegetables + "Tamarin powder"

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
7h30	*AD LIBITUM* TAMARIN GRUEL (remove leftovers 13h30)						
11h30	C. Croc* + Hard boiled egg	Sultanines + Boiled chicken meat	C. Croc* + Mealworms + Tamarin cake	Cheese	C. Croc* + Hard boiled egg + Tamarin cake	Sultanines + Boiled chicken meat	C. Croc* + Mealworms + Tamarin cake
	FRUITS (mostly apples) AND VEGETABLES with tamarin powder sprinkled						
17h00	FRUITS (mostly bananas) AND VEGETABLES with tamarin powder sprinkled						

Supplements: *Vitapaulia M four times per week given in Crousti Croc dog pellets, soaked
                Vitamin D3 in the tamarin gruel from November to April

- *"Tamarin gruel" (home-made protein-rich porridge):*

This gruel (semi-liquid mixture) was formulated in 1986 and is composed of 240 g of a special meal mixture ("tamarin powder"), 600 g of banana, 1000 g of water, 150 g of fruit syrup and 6 g of ISIO 4 oil (a mixture of 4 vegetable oils that ensures the best balance of essential amino acids for humans). During winter time, the gruel is supplemented with Vit. D3: resulting winter diets contain an average of 13.70 IU Vit. D3/g dry matter (DM) as compared to 2.82 IU Vit. D3/g DM for summer diets. The Table below shows the incorporation level of this gruel for several callitrichid species: values ranging from 34% to 56% DMI are recorded.

Summary table: intake of tamarin gruel (% DM)

Species	Gruel % DM	Others % DM
Callimico goeldii, nd=119	40,9	59,1
Callithrix geoffroyi, nd=138	48,6	51,4
Cebuella pygmaea, nd=109	43,4	56,6
Leontopithecus chrysomelas, nd=121	56,2	43,8
Sanguinus bicolor bicolor, nd=355	53	47
Sanguinus imperator subgrisescens, nd=197	48,5	51,5
Sanguinus midas midas, nd=126	49	51
Sanguinus oedipus oedipus, nd=149	34,2	65,8
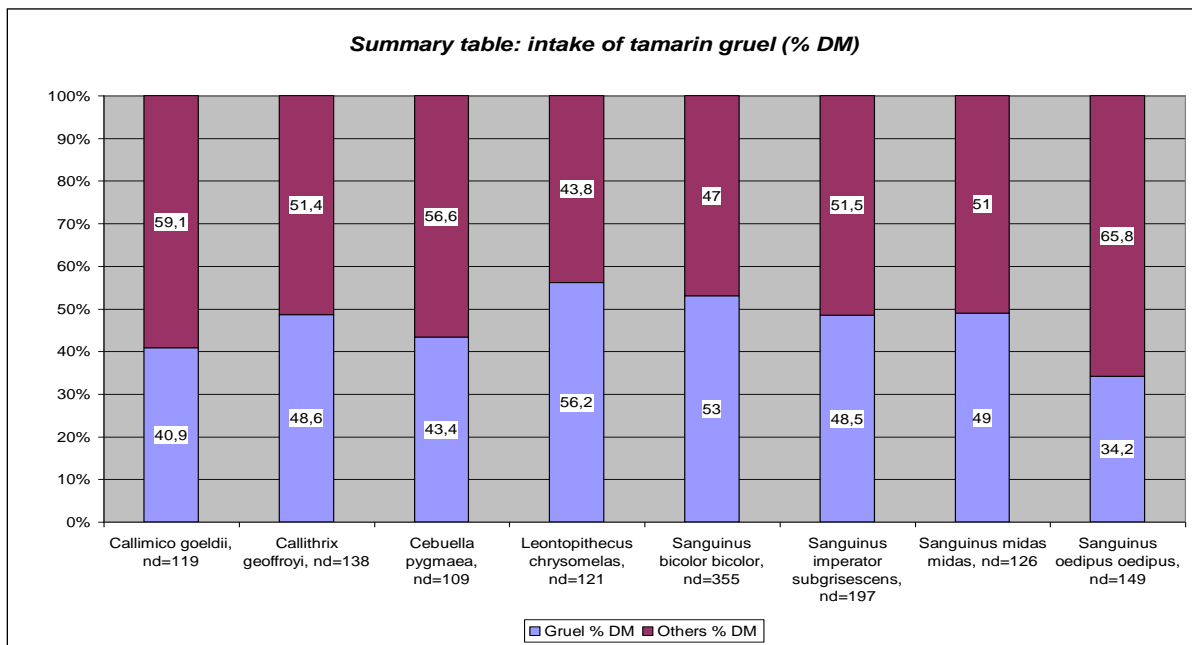
Nutrient composition of Tamarin gruel, DM basis (79.32 % water)
(In winter this is supplemented with Vit D3: Vit. D3 reaches 30.89 IU Vit. D3/g DM)
(Nutrient Quantity Unit)

Nutrient Category: Ash/Minerals	Nutrient Category: Protein
Ash 4.60 %	Arginine 0.67 %
Calcium 1.04 %	Crude Protein 30.76 %
Copper 12.41 mg/kg	Cystine 0.08 %
Iodine 1.18 mg/kg	Histidine 0.57 %
Iron 54.13 mg/kg	Isoleucine 1.03 %
Magnesium 0.56 %	Leucine 1.61 %
Manganese 121.21 mg/kg	Lysine 1.29 %
Phosphorus 0.88 %	Methionine 0.50 %
Potassium 0.62 %	Threonine 0.72 %
Selenium 0.34 mg/kg	Tryptophan 0.20 %
Sodium 0.03 %	Tyrosine 0.87 %
Zinc 90.64 mg/kg	Valine 1.21 %
Calcium/Phosphor ratio 1.18:1	
Nutrient Category: Carbohydrates	**Nutrient Category: Vitamins**
Crude Fiber 6.95 %	Biotin 0.48 mg/kg
	Folacin 1.17 mg/kg
Nutrient Category: Fat	Pantothenic Acid 4.52 mg/kg
Crude Fat 5.23 %	Vit. A 17.15 IU A/g or RE/g
Linoleic Acid 1.31 %	Vit. B1 (Thiamin) 14.80 mg/kg
Linolenic Acid 0.08 %	Vit. B2 (Riboflavin) 1.83 mg/kg
	Vit. B3 (Niacin) 8.62 mg/kg
	Vit. B6 (Pyridoxine) 18.35 mg/kg
	Vit. C (Ascorbic acid) 158.56 mg/kg
	Vit. D3 4.76 IU Vit. D3/g
	Vit. E 179.69 mg/kg

- **"Tamarin powder" (used for "Tamarin gruel"):**

This powder is composed of 200 g Sunflower cattle cake, 160 g lactic casein, 100 g Brewer's yeast, 100 g wheat bran, 7.5 g "dog premix powder", 15 g bi-calcium phosphate and 10 g calcium carbonate. 240 g are used for 2 kg of "Tamarin gruel". The "dog premix powder" is a premix used by the pellet producers and has a general composition which is easy to dilute in powders produced in the zoo. It is interesting to know that on the information tag, the producer indicates the values of nutrients after dilution in a pellet, not the real values in the powder.

Nutrient composition of Dog premix powder, DM base (5.00 % water)
(Nutrient Quantity Unit)

Nutrient Category: Ash/Minerals	Nutrient Category: Vitamins
Ash 54.74 %	Biotin 63.16 mg/kg
Calcium 18.53 %	Choline 200000 mg/kg
Copper 1184.21 mg/kg	Folacin 105.26 mg/kg
Iodine 156.63 mg/kg	Vit. A 2105.26 IU A/g or RE/g
Iron 4736.84 mg/kg	Vit. B12 4.21 mcg/g
Magnesium 1.26 %	Vit. B6 (Pyridoxine) 1052.63 mg/kg
Selenium 42.63 mg/kg	Vit. C 2105.26 mg/kg
Sodium 0.01 mg/kg	Vit. D3 631.58 IU Vit. D3/g
Zinc 7810.53 mg/kg	Vit. E 18947.37 mg/kg
Calcium/Phosphorus ratio ?:1	

Nutrient composition of Tamarin powder, DM base (9.49 % water)
(Nutrient Quantity Unit)

Nutrient Category: Ash/Minerals	Nutrient Category: Carbohydrates
Ash 5.43 %	Crude Fiber 12.25 %
Calcium 1.81 %	
Copper 18.72 mg/kg	
Iodine 2.08 mg/kg	Nutrient Category: Fat
Iron 86.34 mg/kg	Nutrient Qty Unit
Magnesium 0.90 %	Crude Fat 3.28 %
Manganese 209.27 mg/kg	
Phosphorus 1.49 %	
Selenium 0.57 mg/kg	Nutrient Category: Vitamins
Sodium 0.04 %	Biotin 0.85 mg/kg
Zinc 153.87 mg/kg	Choline 62.17 mg/kg
Calcium/Phosphor ratio 1.21:1	Folacin 1.53 mg/kg
	Vit. A 27.97 IU A/g or RE/g
Nutrient Category: Protein	Vit. B1 (Thiamin) 24.84 mg/kg
Arginine 1.05 %	Vit. B12 0.06 mcg/g
Crude Protein 51.34 %	Vit. B2 (Riboflavin) 0.46 mg/kg
Cystine 0.09 %	Vit. B3 (niacin) 0.27 mg/kg
Isoleucine 1.72 %	Vit. B6 (Pyridoxine) 16.36 mg/kg
Leucine 2.64 %	Vit. C (Ascorbic acid) 27.97 mg/kg
Lysine 2.14 %	Vit. D3 8.39 IU Vit. D3/g
Methionine 0.84 %	Vit. E 272.25 mg/kg
Threonine 1.17 %	

- *"Tamarin cake" (offered in winter time):*

After having changed diets by adding extra protein sources (boiled eggs, boiled chicken meat, dog pellets, cheese and crickets), a drier gruel was tested: the ingredients of this tamarin cake are almost the same as the tamarin gruel, but no water and less syrup is added. Intake studies showed that some individuals or groups appreciated it, even if not eaten in huge amounts. After several months, the interest for this new tamarin powder presentation was decreasing in some groups, and we decided to offer it just in winter time. In fact, the keepers observed a lower intake of gruel during this season: thus, it was more interesting to offer it at this time than in summer. This "cake" is composed of 225 g "tamarin powder", 375 g bananas, 6g Isio 4 oil and 18 g fruit syrup.

Nutrient composition of Tamarin cake, DM basis (49.15 % water)
(Nutrient Quantity Unit)

Nutrient Category: Carbohydrates	Nutrient Category: Vitamins
Nutrient Qty Unit	Nutrient Qty Unit
Crude Fiber 8.04 %	Biotin 0.56 mg/kg
	Folacin 1.24 mg/kg
	Pantothenic Acid 3.66 mg/kg
Nutrient Category: Fat	Vit. A 19.34 IU A/g or RE/g
Nutrient Qty Unit	Vit. B1 (Thiamin) 16.85 mg/kg
Crude Fat 5.96 %	Vit. B2 (Riboflavin) 1.51 mg/kg
Linoleic Acid 1.58 %	Vit. B3 (Niacin) 6.71 mg/kg
Linolenic Acid 0.08 %	Vit. B6 (Pyridoxine) 17.73 mg/kg
	Vit. C (Ascorbic acid) 128.38 mg/kg
	Vit. D3 5.51 IU Vit. D3/g
	Vit. E 207.80 mg/kg
Nutrient Category: Ash/Minerals	**Nutrient Category: Protein**
Ash 4.53 %	Arginine 0.74 %
Calcium 1.19 %	Crude Protein 34.95 %
Copper 13.55 mg/kg	Cystine 0.08 %
Iodine 1.37 mg/kg	Histidine 0.61 %
Iron 60.43 mg/kg	Isoleucine 1.17 %
Magnesium 0.62 %	Leucine 1.82 %
Manganese 139.24 mg/kg	Lysine 1.46 %
Phosphorus 1.01 %	Methionine 0.57 %
Potassium 0.48 %	Threonine 0.81 %
Selenium 0.39 mg/kg	Tryptophan 0.23 %
Sodium 0.02 %	Tyrosine 0.99 %
Zinc 102.96 mg/kg	Valine 1.38 %
Calcium/Phosphor ratio 1.18:1	

- *Crousti-croc dog pellets:*

Nutrient composition of Crousti Croc dog pellets, DM base (11.00 % water)
(Nutrient Quantity Unit)

Nutrient Category: Ash/Minerals	Nutrient Category: Carbohydrates
Ash 8.99 %	Crude Fiber 4.49 %
Calcium 1.35 %	
Copper 5.62 mg/kg	Nutrient Category: Fat
Phosphorus 1.12 %	Crude Fat 6.74 %
Calcium/Phosphor ratio 1.21:1	
	Nutrient Category: Vitamins
Nutrient Category: Protein	Vit. A 7.87 IU A/g or RE/g
Crude Protein 22.47 %	Vit. D3 0.79 IU Vit. D3/g
	Vit. E 89.89 mg/kg

- *Vitapaulia M supplement (given in soaked Crousti Croc dog pellets, soaked):*

Vitapaulia M (INTERVET®) is a mineral/vitamin supplement formulated for horse, cattle, sheep, goat, swine, chicken and rabbits, used for all primate species in Mulhouse Zoo.

Nutrient composition of Vitapaulia M, DM base (98.00 % water)
(Nutrient Quantity Unit)

Nutrient Category: Ash/Minerals	Nutrient Category: Vitamins
Cobalt 1580.00 mg/kg	Vit. A 210000.00 IU A/g or RE/g
Copper 4000.00 mg/kg	Vit. B1 (Thiamin) 21000.00 mg/kg
Magnesium 0.37 %	Vit. B3 (niacin) 63000.00 mg/kg
Manganese 307830.00 mg/kg	Vit. B6 (Pyridoxine) 10500.00 mg/kg
Zinc 3395.00 mg/kg	Vit. D3 21000.00 IU Vit. D3/g
	Vit. E 23100.00 mg/kg

- *Resulting intake composition:*

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Diet composition (DM basis) Nutrient	Unit	Leontopithecus chrysomelas	Callithrix geoffroyi	Callimico goeldi	Cebuella pygmaea	Min./Max. recommendations
Nutrient Category:	Energy					
ME Primate	kcal/g	2.24	2.40	2.56	2.37	
Nutrient Category:	Carbohydrates					
Acid Lignin*	%	0.02	0.02	0.03	0.01	
ADF*	%	0.66	0.88	1.20	0.76	5.00/10.00
Cellulose*	%	0.43	0.66	0.91	0.49	
Crude Fiber*	%	4.65	4.32	3.91	4.07	
Lignin*	%	0.04	0.04	0.06	0.04	
NDF*	%	1.00	1.44	1.83	1.27	10.00/20.00
Total Dietary Fiber	%	6.05	6.46	7.66	6.18	
Water Soluble Carbohydrates*	%	0.02	0.02	0.03	0.00	
Nutrient Category:	Fat					
Arachidonic Acid	%	0.00	0.01	0.00	0.00	
Crude Fat	%	4.67	5.14	4.27	4.81	3.00/6.00
Linoleic Acid	%	0.93	0.90	0.79	0.79	
Linolenic Acid	%	0.10	0.10	0.10	0.10	
Monounsaturated Fats	%	0.95	1.06	0.79	0.90	
PUFA	%	0.31	0.40	0.39	0.32	
Saturated Fats	%	0.85	1.03	0.84	1.04	
Nutrient Category:	Protein					
Arginine	%	0.54	0.53	0.42	0.50	
Bound Protein	%	0.00	0.00	0.00	0.01	
Crude Protein	%	22.14	20.97	17.22	20.48	15.00/27.80
Cystine	%	0.09	0.10	0.07	0.08	
Histidine	%	0.46	0.43	0.37	0.43	
Isoleucine	%	0.74	0.70	0.56	0.66	
Leucine	%	1.17	1.11	0.89	1.06	
Lysine	%	0.97	0.92	0.73	0.89	
Methionine	%	0.36	0.34	0.27	0.32	
Nitrogen	%	1.41	1.26	1.02	1.22	
Phenylalanine	%	0.64	0.61	0.49	0.58	
Threonine	%	0.54	0.53	0.41	0.48	
Tryptophan	%	0.15	0.15	0.12	0.14	
Tyrosine	%	0.62	0.58	0.46	0.55	
Valine	%	0.87	0.82	0.66	0.78	

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	Unit	Leontopithecus chrysomelas	Callithrix geoffroyi	Callimico goeldi	Cebuella pygmaea	Min./Max. recommendations
Nutrient Category:	Vitamins					
Biotin	mg/kg	0.29	0.25	0.21	0.24	0.10/0.20
Choline	mg/kg	940.14	774.34	669.73	729.18	/750.00
Folacin	mg/kg	0.92	0.81	0.78	0.81	0.20/4.00
Pantothenic Acid*	mg/kg	5.85	6.12	5.96	5.65	12.00/
Vit A	IU A/g or	18.83	14.37	28.72	14.57	12.50/14.00
Vit B1 (Thiamin)	mg/kg	9.66	8.54	7.35	8.24	1.10/5.60
Vit B12***	mcg/g	0.02	0.02	0.02	0.02	0.60/
Vit B2 (Riboflavin)	mg/kg	2.31	2.43	2.31	2.31	1.70/5.60
Vit B3 (Niacin)	mg/kg	14.24	13.69	13.19	14.62	16.00/56.00
Vit B6 (Pyridoxine)	mg/kg	16.36	14.57	14.39	15.14	2.50/4.40
Vit C Ascorbic Acid	mg/kg	248.84	236.42	288.73	256.26	300.00/500.00
Vit D3**	IU Vit D3/g	13.23	9.47	9.85	10.49	2.20/3.00
Vit E	mg/kg	116.20	101.59	89.92	100.63	56.00/200.00
Vit K	mg/kg	0.50/12.00				
Nutrient Category:	Ash/Minerals					
Ash	%	4.04	3.89	3.76	3.99	
Calcium	%	0.68	0.62	0.54	0.62	0.55/0.75
Ca/P		1.1 1.1	1.1	1.1	1.25/1.5	
Chloride	%	0.20/0.55				
Copper	mg/kg	9.03	8.10	7.56	8.17	12.00/16.00
Iodine*	mg/kg	0.72	0.60	0.52	0.60	0.65/2.00
Iron	mg/kg	38.29	34.57	31.29	33.71	80.00/200.00
Magnesium	%	0.37	0.32	0.28	0.32	0.10/0.20
Manganese	mg/kg	75.70	64.09	55.84	63.39	20.00/100.00
Phosphorus	%	0.60	0.56	0.48	0.55	0.33/0.60
Potassium	%	0.83	0.80	0.88	0.83	0.40/0.89
Selenium	mg/kg	0.22	0.21	0.17	0.19	
Sodium	%	0.04	0.04	0.04	0.05	0.20/0.65

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Diet composition (DM basis) Nutrient	Unit	Saguinus bicolor bicolor	Saguinus imperator subgrisescens	Saguinus midas midas	Saguinus oedipus oedipus	Min./Max. recommendations
Nutrient Category:	Energy					
ME Primate	kcal/g	2.31	2.38	2.38	2.58	
Nutrient Category:	Carbohydrates					
Acid Lignin*	%	0.02	0.03	0.03	0.03	
ADF*	%	0.76	0.72	0.89	1.15	5.00/10.00
Cellulose*	%	0.52	0.47	0.58	0.80	
Crude Fiber*	%	4.45	4.20	4.37	3.72	
Lignin*	%	0.04	0.06	0.07	0.08	
NDF*	%	1.17	1.09	1.34	1.74	10.00/20.00
Total Dietary Fiber	%	6.45	6.31	6.54	7.43	
Water Soluble Carbohydrates*	%	0.01	0.04	0.02	0.03	
Nutrient Category:	Fat					
Arachidonic Acid*	%	0.01	0.01	0.01	0.01	
Crude Fat	%	4.52	4.79	4.89	4.47	3.00/6.00
Linoleic Acid	%	0.90	0.88	0.91	0.75	
Linolenic Acid	%	0.10	0.10	0.10	0.10	
Monounsaturated Fats	%	0.91	0.99	1.02	0.85	
PUFA	%	0.33	0.38	0.38	0.38	
Saturated Fats	%	0.78	0.94	0.98	1.01	
Nutrient Category:	Protein					
Arginine	%	0.50	0.53	0.55	0.44	
Bound Protein	%	0.00	0.00	0.00	0.00	
Crude Protein	**%**	**20.73**	**20.78**	**21.18**	**17.57**	**15.00/27.80**
Cystine	%	0.08	0.09	0.10	0.08	
Histidine	%	0.43	0.44	0.45	0.39	
Isoleucine	%	0.68	0.69	0.72	0.57	
Leucine	%	1.08	1.10	1.13	0.92	
Lysine	%	0.89	0.91	0.95	0.77	
Methionine	%	0.33	0.34	0.35	0.28	
Nitrogen	%	1.32	1.23	1.26	0.99	
Phenylalanine	%	0.59	0.60	0.62	0.50	
Threonine	%	0.50	0.51	0.53	0.42	
Tryptophan	%	0.14	0.15	0.15	0.12	
Tyrosine	%	0.57	0.57	0.59	0.47	
Valine	%	0.81	0.82	0.84	0.68	

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Nutrient Category:	Vitamins	Saguinus bicolor bicolor	Saguinus imperator subgrisescens	Saguinus midas midas	Saguinus oedipus oedipus	Min./Max. recommendations
Biotin	mg/kg	0.26	0.23	0.25	0.20	0.10/0.20
Choline	mg/kg	816.34	718.53	742.92	549.53	/750.00
Folacin	mg/kg	0.88	0.85	0.88	0.78	0.20/4.00
Pantothenic Acid*	mg/kg	6.09	6.45	6.49	6.28	12.00/
Vit A	IU A/g or	21.36	20.10	27.40	24.66	12.50/14.00
Vit B1 (Thiamin)	mg/kg	9.17	8.71	8.90	7.16	1.10/5.60
Vit B12***	mcg/g	0.02	0.02	0.02	0.01	0.60/
Vit B2 (Riboflavin)	mg/kg	2.38	2.54	2.51	2.44	1.70/5.60
Vit B3 (Niacin)	mg/kg	13.44	15.37	15.59	14.76	16.00/56.00
Vit B6 (Pyridoxine)	mg/kg	15.85	15.54	15.56	14.63	2.50/4.40
Vit C Ascorbic Acid	mg/kg	268.32	290.74	322.06	310.82	300.00/500.00
Vit D3**	IU Vit D3/g	11.83	8.25	9.36	7.69	2.20/3.00
Vit E	mg/kg	106.71	97.56	102.37	85.11	56.00/200.00
Vit K	mg/kg	0.50/12.00				
Nutrient Category:	Ash/Minerals					
Ash	%	3.97	4.01	4.01	3.85	
Calcium	%	0.64	0.62	0.63	0.53	0.55/0.75
Ca/P		1.1	1.1	1.1	1.1	1.25/1.5
Chloride	%	0.20/0.55				
Cobalt*	mg/kg	0.00	0.00	0.00	0.00	
Copper	mg/kg	8.53	7.97	8.27	7.32	12.00/16.00
Iodine*	mg/kg	0.64	0.57	0.61	0.48	0.65/2.00
Iron	mg/kg	36.03	33.65	35.30	30.06	80.00/200.00
Magnesium	%	0.35	0.33	0.34	0.28	0.10/0.20
Manganese	mg/kg	69.06	62.24	66.01	52.64	20.00/100.00
Phosphorus	%	0.57	0.56	0.56	0.48	0.33/0.60
Potassium	%	0.86	0.87	0.87	0.90	0.40/0.89
Selenium	mg/kg	0.21	0.19	0.20	0.16	
Sodium	%	0.03	0.04	0.05	0.05	0.20/0.65
Sulfur	%	0.08	0.07	0.07	0.06	
Zinc	mg/kg	53.19	48.80	51.38	41.44	11.00/110.00

*: These values are not reliable and possibly too low. This is because these values are not always entered in ZOOTRITION™ for the feeds which are used in the diet.

FAUNIA MADRID

supplied by: Agustín López Goya

Example: Weight= 410 g (adult)

		Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
M O R N I N G 10h00		VITAMINS (only one of the two examples): 1º) – 1g of Gevral and 3 drops of Protovit in each bowl. 2º) – 1 g of Meritene Vanilla – 2 ml of Calcio 20 Fuerte (*Cebuella pygmaea* and *Saguinus imperator* 4 ml) – 0.15 ml Vit D3 (Berenguer–Infale) (0.03 ml for *Cebuella pygmaea*) – 0.5 g Honey						

		DIET (one of the three examples):
		1º)
		Cereal Pap or Multifruits Pap (without gluten) (3 g in 40ml water)
		    30 g pap/adult animal
		    15 g pap/ subadult animal
		    20 g pap/*Cebuella pygmaea* adult
		2º)
		– 30 g Moist Monkey Food (Zupreem "*Marmoset*")
		3º)
		– 10 g of Monkey Pellets (*Vitafauna "Kasper"*) moist in fruit juices
							Yogurt with honey or jam

		1/6 BOILED EGG	3.5 g CHEESE	5 g BOILED CHICKEN	1/6 BOILED EGG	3.5 g CHEESE	5 g BOILED CHICKEN	Nuts, live food, gelatin, bread...

E V E N I N G 14h00		Fruits and vegetables (see the list below)
		    70 g fruit/adult
		    60 g fruit/*Cebuella pygmaea* adult
		
		Example:
		10 g Boiled Potatoes
		20 g Apple
		15 g Banana
		15 g Orange
		15 g Pear
		10 g Grapes
		10 g Lettuce
		10 g Cucumber
		5 g Tomatoes
		15 g Other Fruits and Vegetables
							Gelatin

			3.5 g Nuts	2 Mealworms	2 Locust	3 Crickets	Only 1 item: –1 Life fish –Arabic gum –10 g Bread	2 Mealworms

Others:

➤ Real food size:
➤ Never more than 25% protein in the diet.
➤ Nuts, hazelnuts, seeds, peanuts, raisins and life food like locusts, crickets, mealworms and zophobas only for treats and enrichments and better in hand.
➤ Eggs; no more than 2 times in a week.
➤ Always fresh water.
➤ For *Cebuella sp*. and Callithrix *sp*.: Agar-agar, gum arabic, gelatin or honey in the branches for enrichment.
➤ Sometimes Bread Yeast.

Iron and Vit. C Concentrations				
FRUIT AND VEGETABLE	**IRON in 100 g of product**	**Vit. C**	**OTHERS**	**FOR A LOW IRON DIET**
Apples	0.18–0.3 mg	3 mg	Better without seeds	Recommended
Pears	0.2 mg	3 – 4 mg	Better without seeds	Recommended
Aubergines	0.4 mg	1.3–5 mg	Boiled	Recommended
Medlars	0.4 mg	2 mg		Recommended
Fresh Cheese	0.3 mg	1.5 mg		Recommended
Rice	White Rice 0.4 mg Integral Rice 1.6 mg	0	Only White Rice	Recommended
Watermelon	0.3 mg	5 mg		Recommended
Gourd	0.4 mg	5		Recommended
Peach and Nectarine	0.4	Peach 6.6 – 8 mg Nectarine 5.4 mg		Good
Plums	0.1–0.4 mg	3–9.5 mg		Good
Celery	0.4–0.6 mg	7 mg		Good
White Grapes	0.26–0.41 mg	4.2–10.8 mg		Good
Black Grapes	0.26 mg	10.8 mg		Good
Apricot	0.4 mg	7		Good
Grenades	0.5 mg	7 mg		Good
Cucumber	0.3 mg	8 mg		Good
Lettuce	0.3 – 0.5 mg	8 mg		Good
Beet	0.4 – 0.8 mg	4.9 mg		Good
Eggs	White of Egg 0.1 mg Yolk 7 mg	0 mg	Boiled Never the Yolk	Good Only the White of Egg
Bananas	0.31–0.4 mg	9.1–10 mg		Good
Cherries	0.4 mg	5–15 mg		Good
Potatoes	0.5 mg	7.4–17 mg	Boiled	Good
Carrots	0.8 mg	Fresh 9.3 mg Boiled 2.3		Good
Maize	Dried 2.7 mg Fresh 0.52–0.9 mg	Dried 0 mg Fresh 6.8–9 mg		Good
Lentils	6 – 7.6 mg	0 mg		Not recommended

Iron and Vit. C Concentrations				
Boiled Chick-peas	6.7–7.2 mg	4 mg		Not recommended
Cauliflower	0.5–1.1 mg	60 mg		Not recommended
Pasta	1.4–1.6 mg	0 mg		Not recommended
Boiled Spinach	3–4 mg	25 mg		Not recommended
Beans	0.8 mg	23.4 mg		Not recommended
Raisins	2.59–2.7 mg	0 mg		Not recommended
Strawberries	0.7 mg	60 mg		Not recommended
Avocado	1.5 mg	15 mg		Not recommended
Melon	0.8 mg	25 – 42 mg		Not recommended
Blackberries	0.9 mg	20 mg		Not recommended
Broccoli	1.5 mg	110		Not recommended
Mango	0.13 mg	27.7 mg		Not recommended
Orange	0.3 mg	50 mg		Not recommended
Papaya	0.42 mg	61.8 – 80 mg		Not recommended
Pepper	0.4 mg	Red 190 mg Green 89.3 mg		Not recommended
Tomatoes	0.4 mg	19 mg		Not recommended
Pineapple	0.4 mg	25 mg		Not recommended
Kiwi	0.51 mg	105 mg		Not recommended
Coconut	2.1 mg	2 mg		Not recommended
Peas	1.9 mg	25 mg		Not recommended

DURRELL WILDLIFE CONSERVATION TRUST

Supplied by: Dominic Wormell

08h00: Pellet breakfast mix

This comprises Skinners Primate pellets which are soaked in honey water overnight. Approx 30g is given per tamarin per day, 25g for marmosets.

Banana puree mix is added on top of the pellet. For approx 60 individuals, this consists of:

5 bananas
2ml D3 oil during winter months or if animals confined inside
Probiotic (10 g powder)
Calcium lactate (10g powder)
Aloe vera (approx 20ml)
Liquid gum arabic (300ml)
blended together to form a smoothie. Approximately 15ml of smoothie per individual per day.

12h00: Fruit/veg and protein feed

The fruit and vegetables are chopped and mixed loosely together. The chopping, as opposed to giving the fruit whole, is to allow a selection of food items to be easily obtained by all animals within groups, whole fruit can be easily monopolised by dominant individuals.
Grapes have been excluded from diet as it was found that they cause diarrhoea in the pieds.

Fruit and veg feed is approx 100g per tamarin and 75g per marmoset.

16h00: Insect/snack feed

This is a small feed of insects and bread soaked in honey water (cut up into small pieces). Insects: Mealworms (only very occasionally), waxmoth larvae, locusts. Locusts are given every day to animals with special requirements or that are more sensitive.

When available, insects (crickets or mealworms) are given as forage feeds in enrichment boxes.

Additional supplements

It is extremely important that all *Callithrix/Mico* species receive gum arabic on a daily basis, approx. 20 mg per animal per day. The gum is a rich source of calcium as well as being high in polysaccharides.

TWYCROSS ZOO

supplied by: Pat Milham

For one adult:

BREAKFAST

1 tbsp soaked pellets (consists of 1 box Milupa (baby food), 150g Trio munch and 2 tbsp Complan)
0.1ml Haliborange (0.05ml for pygmy marmosets)
2 pieces apple = 10g (1 per pygmy = 5g)
2 pieces banana = 8g (1 per pygmy = 4g)

MIDDAY

soaked sultanas = 6g (3g per pygmy)
2 pieces marmoset jelly = 8g (1 per pygmy = 4g)
1/6 boiled egg (1/12 per pygmy)
sunflower seeds = 1g (0.5g per pygmy)
mealworms and/or locusts

TEA

2 pieces each of the following (1 piece per pygmy – weight in brackets)

peeled orange = 8g (4g)	pear = 10g (5g)
cucumber = 12g (6g)	swede = 8g (4g)
tomato = 8g (4g)	banana = 8g (4g)
apple = 10g (5g)	parsnip = 10g (5g)
celery = 8g (4g)	carrot = 10g (5g)
grapes = 12g (6g)	

EXTRAS

2 pieces extra vegetable per animal (1 per pygmy)
aubergine = 6g (3g)
courgette = 8g (4g)
pepper 8g (4g)

SUPPLEMENTS

Vionate powder sprinkled on teas daily
0.1ml (0.05ml for pygmy) Vit D3 once per week
Calci-vit in drinking water daily – 20ml in 1 litre

NOTE   Gum Arabic always available

2.3   Social structure and behaviour

All of the marmosets and tamarins are very social; they engage in a variety of social behaviour and communicate with conspecifics primarily using visual, auditory and olfactory modalities. With the exception of *Callibella*, they rear their young cooperatively (e.g. Caine 1993; Van Roosmalen and Van Roosmalen, 2003). There is evidence that such a cooperative rearing system has led to increased attention towards group members, to an improved ability to coordinate actions, increased social tolerance, and increased responsiveness to others' signals compared with closely related primate species (Burkart and Van Schaik, 2010).

2.3.1   Group Structure

In the wild, callitrichids are territorial, with flexible mating systems. Analyses of group size in shows that *Callithrix* and *Mico* tend to live in larger groups than *Cebuella*, *Saguinus*, *Leontopithecus* and *Callimico* (e.g. Ferrari and Lopes Ferrari, 1989; Rylands, 1993; Soini, 1993; Rehg, 2009). Few data are available for *Mico* but *M. humeralifer (*formerly *Callithrix humeralifer)* group sizes range from 4–13 (Rylands, 1981). *Callithrix* groups usually contain between 3 and 15 individuals (e.g. *C. jacchus* Hubrecht, 1984; Scanlon et al., 1989; Digby and Barreto, 1993) with mean group sizes of 9–11; *Cebuella* group size ranges from 2 to 9 individuals, with a mean of 5–6 (Ferrari and Lopes Ferrari, 1989; Soini, 1993); *Saguinus* live in groups ranging up to 19 individuals but mean group sizes range from 3 to 7 depending on species (Ferrari and Lopes Ferrari, 1989). *Leontopithecus* are more similar to *Saguinus*, with a range of 2–11 individuals and mean group sizes ranging from 4 to 7 (Rylands, 1993). *Callimico* group size is usually 7–9 individuals (e.g. Buchanan-Smith, 1991; Rehg, 2009). Occasional solitary individuals have been observed for all species studied. Often there is more than one adult of each sex in groups (e.g. *C. jacchus* Hubrecht, 1984; *M. humeralifer* Rylands, 1981; *S. geoffroyi* Dawson, 1977; *S. oedipus* Neyman, 1977; *S. mystax* Garber et al., 1984; Soini, 1987; *S. fuscicollis* Terborgh and Wilson Goldizen, 1985). There have also been numerous cases reported of two reproductive females in one group in *C. jacchus* (Digby and Ferrari, 1994; Digby 1995; Ferrari and Digby, 1996; Roda and Mendes Pontes, 1998; Arruda et al., 2005; de Sousa et al., 2005), although breeding is often alternated or one set of offspring does not survive, sometimes due to infanticide by the other breeding female (Digby, 1995; Roda and Mendes Pontes, 1998). Groups are relatively stable, *Callithrix* possibly more than *Saguinus* (Ferrari and Lopes Ferrari, 1989), although there are immigrations, emigrations, births and disappearances (e.g. Arruda et al., 2005). Females cycle throughout the year and males copulate with females throughout the year, including during pregnancy. Females ovulate soon after parturition, and can conceive again shortly after birth, when they are still lactating.

Despite the variety of social structure seen in the wild, in captivity groups are most stable when they consist of a heterosexual breeding pair and their offspring (e.g. Carroll, 2002; Gerber et al., 2002a, 2002b). Sexual behaviour is inhibited in subordinate females by pheromones, visual stimuli and aggression from the breeding female (e.g. Saltzman et al., 1997). Occasionally polygynous mating has been observed in captivity but the groups are less stable than those that consist of monogamous pairs (Carroll, 1986; Rothe and Koenig, 1991).

Callitrichid social and parenting behaviour has a large learnt component. It is vital, therefore, that young are left within their natal group as long as possible in order to gain social experience. As reproductive suppression occurs within groups, it is possible to leave offspring with their parents long after they are full grown. It is desirable for individuals to get caring experience with two sets of younger offspring, which requires offspring to be left in their family groups for a minimum of 13 months and preferably longer if space allows for peaceful cohabitation. Early removal of young results in socially incompetent adults with poor success in rearing their own offspring (e.g. Tardif et al., 1984a, 1984b). This applies to sons as well as daughters, because fathers as well as mothers care

for the young. While it is desirable for young to experience the rearing of younger siblings, this is not always possible, for example due to cessation of breeding in the group. In these cases individuals should stay with group mates at least until maturity, and if required for breeding be paired with an experienced mate. Infant care can also be learnt through successive births.

A fascinating twist that may underpin the evolution of cooperative rearing has recently been discovered (Ross et al., 2007) and awaits confirmation. Due to genetic chimerism (when an animal has genetically distinct cells that come from different zygotes and are created by fertilized eggs, embryos or placenta chorions fusing together) the patterns of relatedness between twins and between other family members change. This chimerism applies to marmosets and tamarins with multiple births because in the womb, placentas grow quickly and their chorions fuse, creating a network of blood vessels through which cells can travel from one twin to the other. Chimeras may exist in almost any part of the body – blood, hair, liver, and even in germ cells, i.e. sperm and eggs. In such circumstances a twin will carry the genetic information of the other in their sperm or eggs, and as a result, one brother may contribute the genetic makeup of his twin brother's offspring, effectively fathering nephews or nieces! The full implications of this phenomenon have yet to be explored, but in addition to the scientific interest in its role in the evolution of the cooperative rearing system, it may have implications for population management in captivity and optimal maintenance of genetic diversity (Buchanan-Smith, 2010).

2.3.2   General behavioural repertoire and communication

As diurnal social primates, callitrichids exhibit the range of behaviour expected for such a lifestyle. Maintenance behaviours include foraging, feeding, self grooming, etc. Affiliative behaviours include resting in proximity, sleeping in a huddled group (usually among vines, in forks of tree trunks, on large branches, in palms or in tree hollows, see Heymann, 1995; Smith et al., 2007), allogrooming, playing, food sharing, courtship and mating. Providing appropriate furnishings to promote such affiliative behaviours is important. These may include large horizontal branches to allow grooming, and soft flat surfaces such as hammocks for play, and huddling. Agonistic behaviour includes aggressive posturing, aggressive approaches and occasionally, physical fighting. Such aggression is arguably more common in captive *Saguinus* than *Callithrix* (see Prescott and Buchanan-Smith, 2004), and the appropriate use of visual barriers may reduce the frequencies of such behaviour, together with maintaining other groups of the same species out of visual contact, as occasionally aggression can be redirected towards group members.

Despite their immense value in understanding behaviour and interpreting welfare, producing full ethograms has rather gone out of fashion. The best behavioural and vocal ethograms for the callitrichids are those in the two volumes of *Ecology and Behavior of Neotropical Primates* (*Cebuella* Soini, 1988; *Callithrix* Stevenson and Rylands, 1988, see also Stevenson and Poole, 1976; *Saguinus* Snowdon and Soini, 1988; *Leontopithecus* Kleiman et al., 1988; *Callimico* Heltne et al., 1981). Unlike the marmosets (*Callithrix*, *Mico* and *Cebuella*, no data available on *Callibella*), the tamarins (*Saguinus* and *Leontopithecus)* do not use genital displays in inter-group encounters, or towards other threats. *Goeldi's monkeys* has an "arch-bristle-leap" display that is used to mob ground predators in the wild, or towards the public and keepers in captivity (Carroll 1985).

Communication between and within groups is visual, acoustic and olfactory. Visual communication includes a range of facial expressions and body postures as described in the ethograms. Like other simians, vision is the dominant sensory modality of callitrichids. It should be noted that all male and some female callitrichids are dichromatic (colloquially colour blind) whilst some females are trichromatic, having vision similar to humans. This raises questions about why some callitrichids are so colourful and has implications for captive studies and choice of colour for targets for positive reinforcement training (Buchanan-Smith, 2005).

As both predators and prey, callitrichids use sight to detect prey items and potential threats. They spend a considerable proportion of time engaged in vigilance behaviour in captivity and such alertness has been found to increase after stressful events (Bassett et al., 2003). Marmosets perform headcocking where they move their heads in the lateral direction. Young *C. jacchus* headcock more than older marmosets, and often this is in the context of novelty (Stevenson and Rylands, 1988). *Saguinus* perform a behaviour termed head flicking by Snowdon and Soini (1988), but it should not be confused with headcocking – head flicking is directed towards conspecifics as a hostile display. *Leontopithecus* will sometimes bob and up and down when staring threateningly (Kleiman et al., 1988).

The vocal repertoire of callitrichids is large, and there are calls used in specific contexts. Several vocal ethograms have been published including that of *C. jacchus* (Stevenson and Rylands, 1988); *S. oedipus* (Cleveland and Snowdon, 1982); *Leontopithecus* (Kleiman et al., 1988) and *Cebuella* (Soini, 1988). The long calls, which serve many possible functions including group defence against intruders, maintenance of group cohesion (e.g. reuniting separated group members), and mate attraction, have been studied extensively (e.g. Pook, 1977; Cleveland and Snowdon, 1982; Snowdon, 1993). Vocalizations are also important indicators in welfare assessment (Jones, 1997). Callitrichids can hear higher frequencies than humans (see Heffner, 2004 for a review). Ultrasonic frequencies present in the captive environment, such as a dripping tap, trolley wheels or computer monitors may adversely affect welfare (Clough, 1982).

Olfactory communication is well developed with three scent gland fields being present in the sternal, suprapubic and circumgenital areas (see Epple et al., 1993). There are taxon specific differences in the relative size of these scent gland fields. *Callithrix* spp, for instance, have large circumgenital fields, with little obvious development of the sternal gland area. *Callimico* has a very obvious sternal scent gland, while *S. oedipus* has a large suprapubic gland. Olfactory communication is extremely complex both within and between species. Scent marks contain information on individual identity, rank and reproductive status, and play a role in reproductive suppression of subordinate females. They may also aid territorial defence, inter-group spacing and provide cues as to mate quality (Epple et al., 1993). The rate of scent marking in wild *C. jacchus* ranges from 0.19 scent marks/hr to 0.45 scent marks/hr (Lazaro-Perea et al., 1999), often much lower than is seen in captive conditions (Bassett et al., 2003). Adults scent mark more frequently than young in captivity (de Sousa et al., 2006). It is vitally important that scent marks are left to accumulate within enclosures. Scrupulous cleaning should not be carried out. When animals are transported, or are moved to another cage location, it is important that they are accompanied by an item of cage furniture that carries their scent marks.

Differences in foraging and feeding behaviours have been noted in relation to sensory adaptations. Tamarins are insectivore–frugivores and their dentition is not adapted for gnawing, unlike that of the marmosets. The long slender hands and fingers of *Leontopithecus* are used for probing for concealed prey in specific microhabitats. A considerable proportion of prey items are located by touch rather than sight, and the most important foraging site is epiphytic bromeliads. There are also differences in foraging strategies amongst *Saguinus* (see Garber, 1993). More information is given in sections 1.6 and 2.2.

2.3.3   Groups in captivity

In spite of the range of group structure seen in the wild, as noted above, captive groups other than monogamous groups are rarely stable for long. In captivity, groups should comprise a single pair and their offspring. Relationships within groups are usually very amicable, with overt aggression rarely being seen. A dual dominance hierarchy has been reported with the breeding male and breeding female co-dominant over the younger males and females respectively. Behaviour studies have revealed, however, that the social group dynamics are, in fact much more complex.

Groups in the wild are territorial and visual contact between captive groups of conspecifics is stressful and must be avoided.

Group formation

Breeding groups should be formed by putting an adult male with an adult female. Ideally, the introduction should be a "soft introduction" with the two animals having visual and auditory contact with each other before being mixed. The introduction should, if possible, be carried out in neutral territory, or by allowing access to each other's home cage rather than in the home cage of either animal. Having said that, aggression between newly mixed heterosexual pairs is usually slight and short-lived, even if they are introduced into an existing home cage area. Newly mixed pairs will often be seen allogrooming, or sitting in contact within hours of being mixed. Problems of incompatibility are rare, and may be associated with an underlying behavioural problem (e.g. abnormal behaviours as a result of hand-rearing or long isolation). General practical guidance on managing primate introductions in laboratory situations is provided in the JWGR report (2009).

If circumstances require it, it is also possible to introduce an adult to an opposite sexed adult with young. This is sometimes necessary if one adult dies leaving a partner with young of various ages. Care should be taken, and the proposed "step-parent" should be allowed to interact with his/her intended pair mate for a short period in the absence of other family members, who may mob the unfamiliar group member (Tardif et al., 2003). The older the young in the group, and the more young there are, the more difficult the mixing will be. Aggression may occur between the new animal and juveniles or subadults of the same sex. In general it is better to remove any young animals that are older than about a year and that have infant-rearing experience. With very young infants it is better to allow them to progress beyond the neonatal stage before introducing a new male. Infanticide has been recorded among marmosets and tamarins, due either to incompetent parenting or to the introduction of a mother with dependent young to unfamiliar conspecifics. A soft introduction must be carried out in the latter circumstances, and the group monitored carefully to assess aggressive interactions.

Group stability and group management

In general, callitrichid groups are very stable over long periods of time and may grow to group sizes of 12 or more in captivity if space allows (e.g. Price and McGrew, 1990; Badihi et al., 2007). Where groups contain young that are of adult age (15–21 months, see Yamamoto, 1993 for species differences in rates of development), however, individuals may become peripheralized and eventually expelled from the group. In many cases peripheralization may take place over a day or so, and although fighting takes place, severe injury is unusual. However, severe aggression can occur without warning and is often associated with severe injury. Deep bite wounds may be inflicted and deaths have been known to occur as a result of such aggression (e.g. de Filippis et al., 2009).

When peripheralization or overt aggression occurs it is unlikely to be resolved by any other means than removal of either the aggressor or the victim. The choice of which to remove will be determined by the extent of injury, the extent of peripheralization and the age and social status of the participants. If, for instance, aggression is by a parent towards an offspring, the offspring should be removed. On the other hand, aggression is often seen between siblings, and it may be better to remove the aggressed sibling (if old enough) rather than the dominant animal. Removal of a dominant sibling may result in changes of dominance relationships that result in further aggression and peripheralization. Groups should, therefore, be monitored carefully following the removal of any animal, and particularly a dominant animal.

Among large lion tamarin groups, sequential events of aggression, peripheralization and removal of animals have been known to result in the complete, or almost complete, breakdown of a

group. A group of over 12 at Jersey Zoo was reduced to three animals over a period of nine days. In order to manage groups to avoid such events, groups should be maintained at about six to eight individuals by removing older offspring at an appropriate time. Groups in which young are removed regularly may remain stable for many years. Providing large complex enclosures with places to hide from group mates allows larger groups to co-exist peacefully.

2.3.4   Mixed-species exhibits

In the wild, callitrichids coexist with many other species of animals, sometimes forming close associations with them. Therefore housing different species together with callitrichids is one way to enrich them socially, as mixed-species exhibits provide a more dynamic and varied environment (e.g. Leonardi et al., 2010). There are some callitrichids that actively associate together in the wild: *Saguinus fuscicollis* with one of *S. mystax*, *S. labiatus*, *S. imperator* or *M. emiliae*, and occasionally the *Saguinus* pairing forms trispecific groups with *Callimico* (reviewed in Heymann and Buchanan-Smith, 2000). Indeed, studies at Belfast Zoological Gardens indicate that naturally associating species actively choose to be in proximity in captivity – when given the opportunity to separate in a free-ranging situation, members of the *S. labiatus* and *S. fuscicollis* mixed-species groups remained within 5m of each other for most of the time (Hardie et al., 2003). Exhibiting callitrichids in their appropriate social context also allows the viewing public to gain greater understanding of the species' natural environment, and observing interspecific interactions may create a more interesting and enjoyable viewing experience (Xanten, 1992; Hardie et al., 2003; Dalton and Buchanan-Smith, 2005).

Mixed-species exhibits may be particularly beneficial for zoos where each species is below natural group sizes; by living in mixed-species groups the increased social complexity may lead to higher levels of both physical and psychological stimulation, enhancing primates' well-being (e.g. Heymann et al., 1996; Thomas and Maruska, 1996; Hardie, 1997; Buchanan-Smith, 1999). A number of positive inter-specific affiliative interactions have been observed amongst individuals in mixed-species groups, including grooming, play, huddling, sleeping together, solicitation and mating (Heymann and Sicchar-Valdez, 1988; Hardie et al., 2003). As they would in the wild, individuals attend and respond to each other, and they can learn from one other, for example, about the presence, location, quantity of food, or how to solve a novel food task (see Hardie et al., 1993; Prescott and Buchanan-Smith, 1999; Heymann and Buchanan-Smith, 2000). Another potential advantage may be that mixed-species groups are often housed in a larger enclosure than the separate constituent single species would be (Xanten, 1990, 1992; Baker, 1992; Hardie et al., 1993).

Despite such potential benefits, mixed-species exhibits are not without risks. There are health considerations relating to mixed-species exhibits with all possible combinations of animals. It should also be noted that mixed-species exhibits can compromise the ability of keepers to work intensively with some species of callitrichid and it should not be considered for some sensitive specimens or species, when new animals arrive in the collection, for first time breeding pairs, etc. If enclosures are not large, complex, and designed well enough to avoid inter-specific competition, chronic stress will decrease welfare and may lead to increased susceptibility to illness.

Furthermore, not all mixed-species exhibits are successful. Sodaro (1999) conducted a questionnaire study on housing neotropical primates in mixed-species exhibits, gaining information on the successful combinations, the failures and the methods of introduction used. Of 50 separate attempts reported with 16 different callitrichid species, the success rate was around 66%. The results from this survey indicate that even the best planning and introduction methods do not guarantee successful long-term cohabitation, and interspecific interactions should, like intraspecific interactions and relationships, be regarded as ever changing. In comparison with traditional housing of single-species groups, mixed-species troops may require higher levels of monitoring to ensure welfare is not compromised (Sodaro, 1999; Dalton and Buchanan-Smith, 2005; Leonardi et al., 2010). Particular attention should be paid around times of change, such as births, deaths or other changes to group

size or structure, and as juveniles mature. Although there are many factors contributing to how successful the captive primate mixed-species groups will be, whether they actively form associations in the wild is a key consideration (Hardie et al., 2003).

One can divide mixed-species exhibits into three different types:

Type 1. One enclosure where two or more species are living together permanently.

Type 2. Each species has its own enclosure for the night and in daytime they have a communal enclosure.

Type 3. Single specimens from different species are put together for companionship.

The descriptions of the mixed-species exhibits described below are primarily based upon the questionnaire findings of Sodaro (1999) and a survey reported by Carroll (2002).

Callitrichids with non-callitrichid*s*

Callitrichids have been exhibited with a variety of different animals which were kept in the same enclosure permanently with callitrichids (Type 1). Combinations with birds or reptiles (e.g. turtles, iguanas and some other lizard species) have been successful, although tamarins in one zoo were reported to chew on the crests of adult green iguanas; one iguana eventually retaliated and bit the tail of a young tamarin! Other mammal species such as rodents (e.g. agouti, acouchi, or rock cavies) have been successful, but there are also reports of them being prone to aggression towards callitrichids, resulting in injuries, or in some cases deaths (Sodaro, 1999). There is one report that acouchis preyed upon newborn tamarins that fell to the ground (Sodaro, 1999). Other successful cohabitants include guinea pigs, sloths, tree porcupines, some other primates and small hoofstock.

One key to mixing different species is to make sure they do not share (or compete for) common resources (e.g. nest-boxes, food, water, resting or basking spots, etc) (Dalton and Buchanan-Smith, 2005). All the species listed above use a different layer of the enclosure, or do not have the same climbing skills as the callitrichids, and are not predators or prey of callitrichids. It is important to remember that callitrichids do take eggs and young birds from nests if they can.

When mixing callitrichids with animals that have less well-developed climbing abilities, it is recommended to:

➢ Give both species a refuge to which they can retreat to be by themselves if necessary (Type 2).

➢ Make sure all the species in the enclosure can eat without disturbance (e.g. temporarily separate them, or, when there are large size differences, provide the smaller animal with feeding sites that are not accessible to the larger species).

➢ Ensure the enclosure is furnished in such a way that there are enough escape routes.

Examples where groups of callitrichids are kept with other primates are shown in Table 2.3.4.2-1 It should be noted that there are potential disease issues to be considered when mixing certain species. For example, it is recommended not to mix Callitrichidae with squirrel monkeys *Saimiri* spp., because of the risk of transmission of Herpesvirus saimiri (see also Section 2.7 Veterinary Issues).

Although there are some examples of keeping callitrichids together with various lemur species and woolly monkeys (*Lagothrix*), most zoos choose a combination with smaller cebids like *Pithecia*, *Callicebus*, *Saimiri* (in spite of the veterinary concerns) or *Aotus*.

Callitrichids with callitrichids

Keeping two groups of different species of callitrichids together is often tried in various combinations with mixed results (see Table 2.3.4.2-2). It appears that the main factors for success are whether the species naturally associate, together with the individual temperament of the animals concerned (Hardie et al., 2003). The behaviour of one individual can change the dynamics of the entire group and, even after years of peaceful compatibility with another species, may result in fighting and irreversible incompatibility of the groups.

Leontopithecus and *Callithrix*, and the naturally associating *Saguinus* species (*S. fuscicollis*, *imperator*, *mystax* and *labiatus*) seem to be the most successful genera to mix. A natural combination of a trispecific troop of *S. labiatus*, *S. fuscicollis* and *Callimico* was successful until a cold spell, when the monkeys were forced into close proximity in a smaller heated area (Hardie et al. 2003). This again emphasises the need for large spacious enclosures – both indoors and out, and available retreat areas so that close proximity can be avoided. Mixing groups of *S. oedipus* with any other callitrichids has been notably less successful. Combining two groups from the same species has no chance of success and is, therefore, not recommended.

Keeping single animals of different callitrichid species together (Type 3) is definitely possible and has been successfully done in a number of different institutions. Various combinations (even with *S. oedipus*) have been tried without problems (see Table 2.3.4.2-3), but this also depends very much on the individual behaviour of all animals involved. It is important to give all animals their own sleeping box even when they choose to use the same sleeping box. Callitrichids of different sexes of the same species but of different subspecies should not be put together due to the serious risk of interbreeding, which must be avoided. Animals of the same sex, however, or of different sexes when one is sterilised to prevent breeding, can be put together.

2.3.4.1   Methods of introduction

Preparation and methods to introduce different species to each other are similar to introducing conspecifics. Prior to mixing it is important that individuals become familiar with each other and establish dominance. Providing auditory, visual, and olfactory contact can be done before physical touching through a wire mesh. It is also considered important that each species is allowed to become familiar with the new enclosure, individually, prior to mixing so that they can learn the physical terrain of the exhibit, potentially reducing the likelihood of being injured during falls or other accidents if chased by others. However, it is understood that this preparation period may not be feasible in all cases and whilst familiarisation with the different species and enclosure is preferable, some introductions have succeeded without it (Sodaro, 1999). Mixing on neutral territory may also reduce the likelihood of aggression between the different species.

2.3.4.2   Mixed-species tables

The tables below are examples of mixed-species exhibits involving callitrichids from two surveys undertaken to look at combinations and successes of mixed exhibits (Sodaro, 1999; Carroll, 2002). These EAZA guidelines do not recommend or advise against any of the combinations given below (unless otherwise noted) as there is no fixed rule for what works and what does not work. The type is given where known.

Table 2.3.4.2-1: Groups of callitrichids together with primates of other families

Species 1	Species 2	Type	Remarks
Cebuella pygmaea	*Pithecia pithecia*		
Cebuella pygmaea	*Callicebus moloch*		Two unsuccessful attempts
Callithrix jacchus	*Pithecia pithecia*	2	One unsuccessful attempt
Callithrix jacchus	*Ateles geoffroyi*		
Mico melanurus	*Callicebus moloch*		One unsuccessful attempt
Leontopithecus chrysomelas	*Pithecia pithecia*		One successful and one unsuccessful attempt
Leontopithecus chrysomelas	*Pithecia pithecia + Cebuella pygmaea*		
Leontopithecus chrysomelas	*Pithecia pithecia + Callithrix jacchus*		
Leontopithecus chrysomelas	*Aotus trivirgatus*		
Leontopithecus chrysomelas	*Saimiri spp.*	2	Not recommended for veterinary reasons
Leontopthecus chrysomelas	*Saimiri boliviensis*	2	Not recommended for veterinary reasons
Leontopithecus chrysomelas	*Lagothrix* spp.	2	
Leontopthecus chrysomelas	*Alouatta caraya*		One successful, one unsuccessful attempt
Leontopithecus chrysomelas	*Lemur catta*	2	
Leontopithecus chrysomelas	*Varecia variegata rubra*	2	
Leontopithecus chrysomelas	*Varecia variegata variegata*	2	
Saguinus oedipus	*Presbytes entellus*	2	One unsuccessful attempt
Saguinus oedipus	*Alouatta caraya*		
Saguinus oedipus	*Lagothrix lagotricha*		
Saguinus oedipus	*Pithecia pithecia*	2	Several successful, and one unsuccessful attempt reported.
Saguinus oedipus	*Saimiri sciureus*		Not recommended for veterinary reasons
Saguinus imperator	*Pithecia pithecia*	2	
Saguinus imperator	*Lagothrix* spp.	2	
Saguinus midas	*Aloutta caraya*		

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Table 2.3.4.2-2: Groups of callitrichids with other callitrichid species

Species 1	Species 2	Type	Remarks
Cebuella pygmaea	Leontopithecus rosalia		
Cebuella pygmaea	Leontopithecus chrysomelas		Two successful and one unsuccessful attempt
Cebuella pygmaea	Saguinus imperator		
Cebuella pygmaea	Callithrix geoffroyi		One unsuccessful attempt
Callithrix geoffroyi	Saguinus leucopus		
Mico melanurus	Callimico goeldii		One unsuccessful attempt
Mico melanurus	Leontopithecus chrysomelas		
Saguinus imperator	Cebuella pygmaea		
Saguinus labiatus	Cebuella pygmaea		
Saguinus labiatus	Saguinus oedipus		One unsuccessful attempt
Saguinus mystax	Leontopithecus chrysomelas		
Saguinus oedipus	Callithrix jacchus	2	Four unsuccessful attempts
Saguinus oedipus	Saguinus labiatus		One unsuccessful attempt
Saguinus oedipus	Callimico goeldii	2	Unsuccessful
Leontopithecus chrysomelas	Cebuella pygmaea		
Leontopithecus chrysomelas	Callithrix jacchus	2	
Leontopithecus chrysomelas	Callithrix geoffroyi		
Leontopithecus chrysomelas	Saguinus midas midas		
Leontopithecus chrysomelas	Saguinus oedipus		
Leontopithecus chrysomelas	Callithrix argentata		
Leontopithecus chrysomelas	Callimico goeldii		Several successful, and two unsuccessful attempts
Leontopithecus rosalia	Callithrix jacchus	2	
Leontopithecus rosalia	Callithrix melanura		
Leontopithecus rosalia	Callithrix kuhli		
Leontopithecus rosalia	Saguinus oedipus	2	Unsuccessful
Leontopithecus rosalia	Saguinus bicolor		
Leontopithecus rosalia	Callimico goeldii	2	
Leontopithecus chrysopygus	Saguinus bicolor		
Leontopithecus chrysopygus	Saguinus oedipus		

Table 2.3.4.2-3: Individual callitrichids housed together

Species 1	Species 2	Type	Remarks
Callithrix pygmaea	Callimico goeldii	3	
Saguinus oedipus	Callimico goeldii	3	
Saguinus oedipus	Leontopithecus rosalia	3	
Leontopithecus chrysomelas	Saguinus oedipus	3	
Leontopithecus chrysomelas	Leontopithecus chrysopygus	3	Unisex
Leontopithecus chrysomelas	Leontopithecus rosalia	3	Unisex
Callithrix jacchus	Callithrix geoffroyi	3	Unisex

2.4   Breeding

Marmosets and tamarins have a rapid reproductive rate. They typically give birth to twins and there is no period of lactational anoestrus. A post-partum oestrus occurs within 10 days of parturition and conception rate at this oestrus is high. Some breeding females may be almost constantly pregnant. Gestation varies between species. The lion tamarins have the shortest gestation at 128 days, while most other species are reported to have a gestation of around 145 days.

Cottontop tamarins have the longest known gestation at 183 days. Infant care is shared among group members. In most species other group members may participate in infant care by carrying the infant from day 1 or 2. Contrary to earlier reports this is also true for lion tamarins. Goeldi's monkey, on the other hand, is one exception to this, giving birth to a single infant with shared infant care not taking place until week three. Another is *Callibella humilis* which is also reported to have a single infant although only two births have been recorded in captivity (Van Roosmalen and Van Roosmalen).

In captivity the Callitrichidae are effectively monogamous. The dominant pair, who in most groups will be the parents of all other group members, suppress other adults within the group from breeding. This ensures that only the dominant pair breed, and generally means that inbreeding does not occur within groups. Rarely, however, incestuous matings and departures from monogamy occur. In the wild, a much more flexible reproductive strategy is apparent in most species for which good information is available.

These points are discussed in more detail below.

2.4.1   Twinning

The marmosets and tamarins are unique among simians in their habit of twinning. While single infants and triplets are not uncommon among marmosets and tamarins, the most frequent litter size is two (Hershkovitz 1977). Exceptions are *Callimico goeldii* who normally have single infants, and *Callibella humilis* which, as stated above, has only been recorded having single infants, although only two births have been recorded. Molecular data suggest that *Callimico*, *Callithrix* and *Cebuella* are more closely related to each other than to *Saguinus* and *Leontopithecus*, which, in turn, suggests that *Callimico* evolved from a twinning ancestor (Porter, 2007) Occasionally, quadruplet births have occurred, but there are no reports of all four infants being born alive in zoos or in the wild. The incidence of triplets has been reported to increase with time in captive colonies of *C. jacchus* and may relate to a high protein diet in captivity (Hiddleston, 1977). It is unusual for all three infants of a triplet litter to be parent-reared in captivity (J B Carroll, pers. obs.). Evidence from DNA studies has provided good evidence that triplets have been reared to independence in a wild group of *C. jacchus* (Dixson et al., 1992).

Callitrichid twins are dizygotic yet the foetuses share a placenta and amniotic sac. The placenta consists of two fasciated placental discs and there are, therefore, blood vessel connections between the twins. This results in so-called blood-chimerism and as a result, each of twins carries genetic material from the other. This is very rare in other mammals but normal in callitrichids (Hampton, 1973, Hershkovitz, 1977, Haig, 1999, Ross et al., 2007). Where the twins are heterosexual, we can find both xx and xy cells in the each animal, which can be easily demonstrated through examination of karyotypes in blood smears. It has also been demonstrated that chimerism occurs in other somatic tissue, but perhaps most surprisingly in germ cells. Thus an offspring may carry genetic material from not only its sire and dam, but also from the twin of the sire and dam (Hampton, 1973, Ross et al., 2007).

Some considerable discussion has centred around whether twinning is a primitive feature that has been retained, or a derived feature. Hershkovitz (1977) maintained that twinning was a primitive feature, while most other authorities have considered it derived, citing the highly specialised placentation, simplex uterus, and number of teats as evidence (e.g. Ford, 1980, Martin, 1990, 1992).

2.4.2   Reproductive strategies

Care must be taken to distinguish between social group structure and mating relationships when discussing reproductive strategies. The presence in a group of more than one adult of either sex does not necessarily indicate that they are all reproductively active. They may, for instance, be non-reproductive mature offspring of the breeding male or female. In captivity, mature offspring may remain in a stable group and yet not enter a breeding relationship with their parents or siblings, as they are reproductively suppressed. The fact that a female may mate with more than one male is also not conclusive evidence of a polyandrous *breeding* system, although it is obviously suggestive of this. Only when paternity of offspring can be established will the breeding system be understood fully.

In fact, in spite of the many reports of group structure indicating that there may be more than one breeding pair in a wild callitrichid group, only a few studies have actually reported seeing females mated by more than one male. These are in *C. jacchus* (Hubrecht, 1984, *C. humeralifer* (Rylands, 1987), *S. fuscicollis* (Goldizen, 1988) and *L. rosalia* (A. Baker, pers. comm.).   Even fewer studies have reported more than one breeding female in a social group at the same time. Among these are *S. fuscicollis* (Terborgh and Goldizen, 1985), *S. oedipus* (E. Price, pers. comm. to JBC), *L. rosalia* (Baker et al., 1993) and possibly *C. jacchus* (Scanlon et al., 1988).

It is, however, not surprising that there is a paucity of data from wild groups. As Goldizen (1990) has pointed out, the marmosets and tamarins are small, difficult to habituate to the presence of observers, and mating may last only a few seconds. Goldizen's studies have shown, however, that even within a species (*S. fuscicollis*) the reproductive strategy may vary. She found groups to be monogamous, polyandrous, polygynous, and polygynandrous in their mating system. She suggested that this variability is related to demographic effects and the need for helpers to rear offspring successfully (Goldizen, 1990). Infant rearing is discussed more fully below.

2.4.3   Reproductive suppression

Reproductive suppression of subordinate females among captive callitrichid groups is a well-documented phenomenon (e.g. *C. jacchus*, Epple 1972a, 1977, Abbott and Hearn (1987, Abbott 1984; *S. fuscicollis*, Epple and Katz, 1984; *S. oedipus*, Ziegler et al., 1987, Savage et al., 1988).   In *C. jacchus*, hormonal studies of females in peer groups have shown that the behaviourally dominant female is the only female to undergo normal ovulatory cycles (Abbott and Hearn, 1978).   In nuclear family groups, it has also been shown that daughters do not exhibit ovulatory cycles and are therefore also suppressed in the three species *C. jacchus*, *S. fuscicollis*, and *S. oedipus* (Abbott et al., 1981, Epple and Katz, 1984, Savage et al., 1988). In *C. jacchus* some daughters do ovulate (although they do not cycle regularly) while still in their natal group (Abbott, 1984), and rarely this also occurs in *S. oedipus*. In *Leontopithecus*, on the other hand, daughters may undergo normal ovulatory cycles within their natal groups (French and Stribley, 1985, Van Elsacker, 1994). Young females are often subject to severe aggression from their mother when they mature (Kleiman, 1979) and are thus prevented from breeding through behavioural rather than physiological means.

Physiological suppression of female cycles is by no means absolute. There are several instances of breakdown of suppression in the literature (e.g. Abbott, 1984, Carroll, 1987) to suggest that something else is operating to prevent reproductive activity of daughters within their natal groups and effectively acts as an inbreeding avoidance mechanism. Incestuous matings resulting in pregnancy do occur rarely in established breeding groups. If one of the parents of a group is removed it has been reported that in time suppression will eventually cease toi be effective and incestuous breeding occurs. If a breeding male is removed, or dies, and is replaced in a group with the surviving mother and her daughters, it should be expected that the male will breed with the daughters as well as the mother. While the group may remain stable for some time with more than

one breeding female, it should be expected that eventually aggression between the females will occur resulting in the expulsion of one from the group.

2.4.4   Infant care patterns among the Callitrichidae

It has been suggested that twinning has major consequences for the breeding female among the Callitrichidae. Not only must the female carry twin foetuses through pregnancy, she must also rear them to independence.   Kirkwood and Underwood (1984) showed that in captive cotton-top tamarins, *Saguinus oedipus*, energy intake by the female increased during lactation. Price (1990) showed in the same species that, when lactating, feeding rates of females increased to a peak during the second month following birth, and only declined when infants began to receive food from other group members. Dunbar (1988) has used models developed by Altmann (1980, 1983) to predict the costs of twinning to tamarin mothers. His predictions suggested that a callitrichid mother could rear twins only if she did not have to carry them as well. In short, the female needs help if she is to rear both twins successfully. Several researchers have suggested that this is the reason for the communal or cooperative pattern of infant care seen among the callitrichids in which several, if not all, group members are involved in infant carriage and provision of food (e.g. Kleiman, 1977, Sussman and Garber, 1987, Dunbar, 1988, Goldizen, 1990).

Callibella and *Callimico*, both reported to have single infants, differ in their infant care patterns. *Callimico* mothers typically care for their offspring alone for about the first three weeks of its life, after which shared care takes place. Shared care has not been reported at all in *Callibella*. *Callibella* is reported to park infants from about day 5 following birth, but these observations should be regarded cautiously as they are based on only two births in captivity.

Reviewers of the social and reproductive systems of the marmosets and tamarins have attempted to interpret the inter-relationship between the sex ratio of wild groups, the mating systems that they exhibit and the role of helpers providing extra-maternal care of the offspring. These communal breeding systems have been referred to as "cooperative polyandry" (Goldizen and Terborgh, 1986), "facultative polyandry" (Goldizen, 1987), or "functional polyandry" (Sussman and Garber, 1987). The variability shown both within and between callitrichid breeding systems is becoming increasingly apparent. For instance, differences have been highlighted between breeding systems of the marmosets and tamarins that probably relate to fundamental differences in their ecology (Ferrari and Lopes Ferrari, 1989).   It is unlikely, therefore that such generalizations about the callitrichid breeding systems will be sustainable in the future.

2.4.5   Implications for captive management

Marmosets and tamarins breed within a tight cohesive social unit in captivity. For successful breeding stress needs to be minimized and groups should be maintained in their usual enclosure and with their usual group structure. It is vital, for instance, that breeding females are not separated from their groups prior to or at parturition under normal circumstances.

Mating is rarely seen, particularly within established groups of callitrichids. Mating occurs during pregnancy and outside the ovulatory period of the non-pregnant cycle, and hence conception dates are rarely known. As a rule of thumb, pregnancy is detectable visually about two months prior to parturition if it is possible to get a clear view of the abdomen of the breeding female prior to any feeding during the day. At one month prior to parturition abdominal swelling is usually clearly visible. Not all pregnancies can be detected visually and gaining reliable estimates of parturition dates is difficult based on female size, but this is nevertheless a useful indicator of when parturition may occur. Another way to find out if a female is pregnant is by behavioural observation. In most cases when the female is pregnant, she will become (more) dominant over the male, and this can easily can be seen by experienced keepers during feeding time. Also, like most primates, they will

drink more water during pregnancy. These behaviours can be observed about 8 or 9 weeks after conception.

Births almost invariably occur overnight. Many zoos put soft substrate of woodwool or similar material on the cage floor in preparation for parturition in case of falls. Occasionally births occur during the day, but this is usually an indication of a problem, although pied tamarins have been often observed giving birth in the late afternoon rather than overnight. In some species there is a high rate of failure to rear young, such as *S. bicolor* and *S. imperator*. In the event of infants being abandoned by the parents all possible attempts must be made to reintroduce them and induce parent rearing. If this fails, however, handrearing may be attempted, depending on the policy of the species programme where one exists.

Dead and mutilated infants are reported relatively frequently and may be due to several reasons. Stress at the time of parturition may induce infanticide and underlines the importance of reducing stress for these animals particularly at the perinatal period. Behaviourally incompetent parents may kill or injure infants. Overzealous grooming by a parent or sibling may result in injury to infants and should be monitored carefully.

Landmarks in infant development are variable depending on many circumstances such as species, history of the family group (first-time mothers are likely to show later landmarks than established breeding groups), and group composition. In general, however, infants are carried for about two to three weeks, after which time they may be seen taking tentative steps and mouthing food. By six weeks of age locomotion is mostly independent of the parents and weaning is well under way. By twelve weeks they are weaned and capable of independent existence.

As reported in the section on social behaviour, infant care has a largely learnt component. It is vital that young are left with their natal group to experience and participate in infant rearing in order to become competent parents themselves.

2.4.6   Hand rearing

2.4.6.1 The need to hand rear

Hand rearing may be necessary for a variety of reasons – rejection by the parents, ill health of the mother, weakness of the offspring or a triplet birth.

Careful consideration must be given as hand rearing requires a great deal of time and commitment. Unless the individuals are of genetic importance subsequent problems in hand-reared adults may be undesirable. With careful re-introduction they can, and do, breed normally, but can develop behavioural abnormalities and may become extremely aggressive towards their keepers.

Fostering may be considered as a preferred alternative to hand-rearing if a suitable foster mother is available.

If rejected, offspring may be found on the floor or the adults will be agitated, pulling them, trying to rub them off against perches and wire and in some cases biting them severely.

Every effort should be made to keep the baby within the group. Sometimes it is possible to remove the infant and feed it and try returning it to the group later or the next day but it is important to monitor the situation closely.

When infants are rejected or abandoned by parents, diet, grouping, specimen social history etc, must be evaluated. If no specific cause is identified and if stress is considered as a most probable

cause, treatment with a neuroleptic drug can be tried on mother or father or both, but it must not be a substitute to poor housing conditions. For instance, zuclopenthixol can be given orally at 4 to 8 mg/kg every day a few weeks before and after delivery. Dosage has to be adapted to each individual so that sedative effects are not too much. This treatment helps mother (and father if necessary) accept infants and calm down. Then, parents gain experience and may be able to rear the next litter without treatment. There are cases where treatment had to be repeated 2 or 3 times and, at the end, natural rearing occurred.

If the offspring are being cared for but receiving no milk they will be restless, climbing over the adults continuously. As they become weaker they will hang from around the legs or the base of the tail of the parent. The infant's tail, normally held coiled, may be seen extended and limp. Contented babies, when very young, sleep most of the time. When not suckling they will cling tightly around the neck or shoulders of the parent.

In triplet births one baby usually dies. In several species three young have been reared but this is rare. Sometimes one dies very quickly but they may all die after some days as all three may not have received enough nutrition. When removing a triplet the temptation is to take the smallest one, but this one has a better chance with its mother than if hand reared. The largest, strongest baby will respond better to hand rearing. You may consider handrearing two of triplets as they will then grow with each other's company and may become less imprinted. Several institutions, particularly laboratories, have successfully used a system of alternating which of triplets receives food, taking a different infant each day. In zoos animals tend to be handled less than in laboratories and the potential benefits of alternating between the triplets need to be weighed carefully against the stress to the carriers of the extra handling involved.

2.4.6.2   Physical condition of the infant

An incubator is the best source of warmth. Heat lamps are not suitable, the heat is too intense and will dehydrate the babies. If an incubator is not available hot water bottles are good, but use caution and wrap them in several layers of towelling. Small babies die very quickly if too hot. 26.5–29 °C (80–85 °F) is ideal. Heated plant propagators are useful for older youngsters but are not usually warm enough for newborns. In a real emergency a domestic iron on the lowest setting wrapped in towelling in a box can be used as a heat source.

Should the baby be hypothermic when you remove it, you can raise its body temperature gently by holding it against your own body or holding it in your hand in a bath of warm water.

Hot water bottles do have one advantage in being easily transportable. They can be placed in a basket or carrier if you have to take the young ones with you anywhere.

The baby will need something to cling to; a small toy or, if this is not available, a couple of thick socks rolled together will do.

2.4.6.3   Feeding regime

A syringe with a small teat on the end is the best thing for feeding. Dolls' bottles are usually too large and glass ones are awkward to use. Syringes also have the advantage of being calibrated so the amount of each feed can be recorded.

There are many accounts of milk formulae and various additives but experience has shown that a good quality milk substitute for human babies is quite adequate without additional vitamins etc.

Start by feeding the baby every 2 hours. The milk must be warmed to blood temperature; gauge this by holding the syringe against your cheek or wrist. Babies will not take milk that is too hot or too cold. It is best to wait a little while if they have been taken directly from the parents, as they may be distressed and will accept an artificial teat more readily if hungry. Hold the baby in an upright position to feed it, not lying on its back. This will help stop milk being inhaled and going into the lungs which can lead to pneumonia. If they sneeze it out of the nose dab it with tissue to prevent it being inhaled. Introduce the teat to the mouth and, if the baby sucks the teat immediately, release the milk *slowly*! If the infant does not suck at the teat try putting a drop on the lips to see if the baby will lick it. The first feed can be of just glucose or honey and water to start the system gently, the second feed diluted milk and thereafter as per the mixing instructions. The baby may take very small amounts at first, 0.5ml being average for the first few days.

Feed should be given only when the baby is hungry and sucking vigorously, as encouraging it to keep taking more milk can be fatal. Babies will not die of being slightly underfed, but overfeeding will kill them. As the volume of the feeds increases the frequency can be reduced: 3 hourly in the 2nd week, 4 hourly in the 3rd week, etc. Babies will be very hungry at some feeds, less at others, but this is quite normal.

As a basic rule one can say that when the baby drinks 10% of his bodyweight in 24 hours, it will stay alive but will not really grow. Between 15 and 20% is normal and the baby will grow. A maximum of 25% is only given when the animal is dehydrated or if it is underweight and has to catch up.

After each feed, it is necessary to stimulate the baby to urinate and defecate by gently rubbing the anus and genitals with some tissue or cotton wool which should be moistened with warm water. The first motion (meconium), is normally very thick and dark, after which they will be pale yellow. Should the baby become sore around the base of the tail use a little baby cream.

After the first week or so the baby will not need feeding at night – 06h00–24h00 being sufficient. After 4 weeks, very small amounts of cereal-based infant food should be introduced to the milk, gradually increasing it during weeks 5–6. By week 4 the baby will start taking soft banana or pear from your fingers. At this stage start leaving the baby with a small bowl of finely chopped food. By 12 weeks the baby will be fully weaned but may still appreciate some baby cereal in a bowl, particularly if this is not part of your normal adult feeding regime.

2.4.6.4 Monitoring progress

Weighing the babies daily and keeping a record of their weight gain is important. The weight should increase steadily, though not necessarily daily (a little weight loss may occur in the first couple of days). If there is gradual weight loss while they are still being fed milk consult your vet or seek further guidance. When the babies begin to wean and you start withholding bottle feeds a slight weight loss is normal.

Minor digestive problems can occur. Constipation, if the babies have not defecated after a couple of feeds, might be remedied by replacing a milk feed with glucose and water. Using water that has had a handful of rice boiled in it to make up the milk feed may help diarrhoea. The starch in the rice has a binding effect. If diarrhoea is severe and persistent feed the baby an electrolyte solution to ensure it does not dehydrate or lose body salts. If this is done for a couple of feeds it may solve the problem otherwise consult your vet. Be very cautious when using kaolin based remedies as they can cause intestinal blockage.

2.4.6.5   Reintroduction

Reintroduction should be started as soon as possible, and contact with the rest of the natal group is very important. Ideally during the day the infants should be kept within sight, sound and smell of the group, preferably in their container within the enclosure. Once the infants are mobile they should be released for short periods, gradually increasing until they are fully integrated. All interactions should be observed initially. If it is not possible to reintroduce infants to their family, mixing them with a single animal of any callitrichid species can be successful and is preferable to isolation.

Example of weight gain for a cotton-top tamarin (Saginus oedipus) at Lincoln Park Zoo

Age	Weight	Average daily intake
Day 1	34g	6.5cc
Day 26	53g	17cc + solids
Day 48	76g	25cc + solids
Day 69	111g	18cc + solids

Useful references for further information are:.
Saunders, N. and Sodaro, V (1999). Callitrichid husbandry manual, AZA Neotropical Taxon Advisory Group.
Pook, A.G. (1976) Development of hand-reared infants of four species of marmoset, 13th Annual Report, Jersey Wildlife Preservation Trust.
Pook, A.G. (1974) Handrearing and reintroduction of saddle-back tamarin, 11th Annual Report, Jersey Wildlife Preservation Trust.

2.4.7   Population and breeding control

Much of the information below was derived and adapted from the report of the Workshop on *Leontopithecus* population and breeding control held at the Royal Zoological Society of Antwerp, 20–21 November 1998. It does not necessarily reflect, however, a consensus opinion of the workshop or of other individuals involved with the workshop.

The section on chemical and surgical contraception has been updated with current knowledge as of June 2009 by Strike and Feltrer.

2.4.7.1   Introduction

The irony of conservation breeding programmes is that every successful programme at some stage reaches a point where it is desirable to control the growth of the population. This may be because:

- there is a general surplus of animals of the species leading to space problems
- there is a surplus of animals of certain genetic lines which are over-represented
- there is a surplus of either males or females (depending on sex ratio at birth and breeding system of the species)
- there may be a danger, in case of large numbers of surplus animals, of animals ending up in commercial trade or uncontrolled breeding in the primate private sector
- medical and health reasons.

This means that almost every conservation breeding programme sooner or later hits this problem, even if there are not yet a sufficient total number of animals to ensure the viability of the species.

The optimal population control method would be one that:

is effective

The method must prevent breeding and/or keep stable or reduce the population.

is reversible

In case disaster strikes among the offspring and/or other relatives, it is important to still have the option to let contracepted animals breed again. Reversible contraceptives also allow the lengthening of generation time and/or inter-birth interval by getting the animals to start breeding later in life and/or build in breaks between pregnancies at certain stages of life.

is safe and has no physiological/medical side effects (so that physical welfare of the animals is not compromised)

has no behavioural side effects and allows as many natural behaviours as possible to be exhibited

In order to have a population of not just genetically and demographically, but also behaviourally healthy callitrichids, it is desirable for as many individuals as possible to be allowed/able to perform as many aspects of their natural behavioural repertoire as possible.

is easy to use in view of daily animal management and animal welfare

The less invasive the method, the less traumatic the experience for the animal and the easier the management for the keepers, veterinary staff and curators. The more invasive the technique, the longer the anaesthesia and the longer the animals are away from the group. However, anaesthetic drugs and anaesthetic techniques have improved considerably since the last edition of this manual (drugs are safer with fewer residual and side effects) and the authors feel that the need for a brief general anaesthesia should not be a deterrent to using a particular contraceptive method. The method should also not be too expensive so that it is accessible to all institutions "rich" and "poor".

causes little or no negative reactions with the public

The display of groups of endangered animals which are part of a conservation breeding programme but which are prevented from breeding are perceived to be "educationally incorrect" by some zoos because they feel the animals can not be shown "the natural way" (i.e. looking after offspring etc.). When control methods are used which cause negative side effects for the animals or which include euthanasia of individuals, then negative PR becomes an even bigger concern for the participating institutions. On the other hand, some aspects of these perceived negative public relations can be counteracted by thoroughly and honestly educating the public about the problems/issues at hand.

2.4.7.2 Current options for population control

How to choose the appropriate contraceptive/population control method

A variety of factors such as efficacy and safety of available methods, the animal's age, behavioural and social factors, the practicality of different delivery systems, and the individual's reproductive status must be considered when selecting an appropriate population control method. It is unlikely that the same method will be the most appropriate choice during all stages of an animal's life.

2.4.7.2.1 Family groups

The advantage with Callitrichidae is that in normal family groups a system of reproductive inhibition is often in operation whereby offspring do not reproduce with one another or with their parents, as long as they are in their natal group. Reproduction can therefore often be postponed by leaving offspring in their natal groups for a prolonged period of time. This type of "social contraception" is however not 100% effective. Polygyny does occur to a larger or lesser degree depending on the species and circumstances and both in captivity and in the wild (De Vleeschouwer, 2000; De Vleeschouwer et al., 2001).

The mechanisms that limit breeding to a single adult female also differ among callitrichid taxa. Ovarian function of female lion tamarins is not influenced by social factors – the cycles of daughters and subordinate females are indistinguishable from those of breeding adult females (French et al., 2002). It is thought that the non-breeding of daughters and subordinate females in lion tamarins is maintained through behavioural mechanisms but exactly how this works has not yet been shown. Most daughters and subordinate females of other tamarins and marmosets will either not ovulate or show changed ovarian activity. However, it has been observed that some *S. oedipus* females would ovulate in the presence of a reproductive female and some daughters of *C. jacchus* living in the family group showed ovarian cyclicity (French and Snowdon, 1984).

2.4.7.2.2 Unisex groups

Callitrichids can, in general, be kept in small (usually 2–3 animals) unisex groups. Groups of related animals (mothers with daughters, fathers with sons, brothers, sisters) appear to be most stable. Unrelated males can often be introduced to one another without major problems. More problems seem to occur with unrelated females although successful combinations of these have also been formed.

Keeping the animals in single sex groups appears to be an acceptable way of preventing breeding, at least in the shorter term. However, we must be aware of the fact that the animals do not get to practise an important part of their behavioural repertoire (courtship and mating behaviour). The potential negative effects of being in a unisex group for a long time need to be assessed and would be a recommended research project.

2.4.7.2.3 Chemical contraception

Types of chemical contraception

Gonadotrophin Releasing Hormone (GnRH) agonist
      Suprelorin® (deslorelin) implants

Progestagen-containing hormonal contraception
      Melengesterol acetate (MGA) implants
      Medroxyprogesterone acetate (MPA) injections (e.g. Depo-Provera®)
      Norplant (levonorgestrel) implants
      Implanon (etonogestrel) implants

Placement of implants

For some contraception implants the recommendation is to place them between the shoulder blades; however, the authors would recommend the implants be placed subcutaneous in the inner part of the arm. The implants can then be easily located and removed for (1) reversal to breeding or (2) replacement with a new implant.

Gonadotrophin releasing hormone (GnRH) agonist contraception

Suprelorin® (deslorelin) implants:

Product Information: GnRH agonists work by temporarily suppressing the reproductive endocrine system and preventing production of pituitary (FSH and LH) and gonadal hormones (oestradiol and progesterone in females and testosterone in males). The observed effects are similar to those following ovariectomy or castration, but are reversed after the hormone content of the implant is depleted.

Dose: GnRH agonists are considered the safest reversible contraceptives, but dosages and duration of efficacy are not well established for all species. Although deslorelin can also be an effective contraceptive in males, we recommend its use primarily in females, since monitoring efficacy in females by suppression of oestrous behaviour or gonadal steroids in faeces is more straightforward. It can be used to ameliorate aggression in males but higher dosages are usually required.

In New World monkeys, Deslorelin has been used in the bare-faced tamarin, cotton-top tamarin, red-handed tamarin, black tufted-ear marmoset, pygmy marmoset, common marmoset, spider monkey, squirrel monkey, black howler and white-faced saki (AZA WCC database 2008).

Deslorelin implants are available in two formulations: 4.7mg implant for an approximately 6-month contraception period and a 9.4mg implant for an approximately 12-month period of contraception.

It must be emphasized that both implants theoretically release the GnRH agonist at the same rate; therefore, 2 or more implants of 4.7mg will only increase the dose given over the 6 month period (i.e. the duration of contraception does not increase).

Deslorelin is manufactured by Peptech Animal Health, Australia, where both formulations (4.7mg and 9.4mg) are available. Currently in Europe only the 4.7 mg formulation is available and it is distributed by Virbac Animal Health.

Latency to effectiveness: Deslorelin first stimulates the reproductive system, which can result in oestrus and ovulation in females or temporary enhancement of testosterone and semen production in males. Down-regulation then follows the initial period of stimulation. Due to this initial stimulation phase, it is important to either separate treated animals from opposite sex during the period of enhanced fertility (usually recommended as 3 weeks) or use another form of contraception (Megestrol acetate tablets daily, 7 days before and 7 days after the implant has been placed). Depo-Provera® injection should not be used to suppress stimulation phase due to a possible interaction at the cellular level which may inhibit down regulation.

Oestrous cycles during contraceptive treatment: Deslorelin first stimulates then suppresses oestrus in females. In males, initial stimulation may be accompanied by increased aggression or sexual interest.

Duration and efficacy and reversibility: Duration of efficacy and reversibility are not well established for all species.

One reversal has been reported in a female pygmy marmoset after treatment with one 4.7 mg implant (AZA WCC database 2008).

Use during pregnancy: GnRH agonists should not be used during pregnancy, as they may cause abortion.

Use during lactation: No known contraindications once lactation has been established.

Use in pre-pubertals or juveniles: Deslorelin may prevent epiphyseal closure of the long bones, resulting in taller individuals. GnRH agonist use in prepubertal cats was followed by reproductive cycles after treatment ceased; however, species differences may occur (AZA WCC).

Effects on behaviour: The Zoological Society of London has used deslorelin implants in female golden headed lion tamarins and no negative behavioural, social or side effects have been observed (Y. Feltrer, pers. comm.).

Precautions: In general, the effects on weight would be similar to those from ovariectomy or castration (AZA WCC).

Reporting requirements: In order to increase our knowledge of the efficacy of contraception methods in the Callitrichidae family it is recommended that all individuals on contraception be reported to the European Group on Zoo Animal Contraception EGZAC (www.egzac.org). EGZAC works in association with the American Association of Zoos and Aquariums Wildlife Contraception Center (AZA WCC).

Progestagen-containing hormonal contraception

Product Information: Parenteral progesterone analogues (such as MGA, Norplant, Depo-Provera®, Implanon) share the same contraceptive mechanism of interference with fertilization by thickening cervical mucus, interrupting gamete transport, and disruption of implantation. It is important to note that ovulation and cycling can occur but is unlikely and the degree of suppression is dose dependent.

Although these products are good contraceptives, and do not require daily medication events, a short anaesthetic procedure is required to place some of these products (except the Depo-Provera® injection). Anaesthesia can be short and the female can be reintroduced to the family group in less than 2–3 hours. The risk of losing the implant can be avoided by correct surgical technique.

Dose: To achieve effective contraception a much higher dose of progestins is needed for callitrichids and other New World primates than for Old World primates.

Latency to effectiveness: For the implants, although there is individual variation, threshold concentrations of the hormone should be reached in the blood within 1 to 3 days following IM insertion and within 1 week following SQ insertion. However, it the cycle stage is not known then extra time must be allowed; therefore, separation or alternative contraception should be used for at least 1 week (if IM) or 2 weeks (if SQ) following insertion. IM injection is roughly equivalent to implant insertion and therefore follows similar recommendations (AZA WCC)

Oestrous cycles during contraceptive treatment: Follicular growth may continue and therefore accompanied by oestrogen production sufficient enough to cause oestrus. Ovulation may also occur even though pregnancy does not ensue.

Duration and efficacy and reversibility: Parenteral progestins are designed to be reversible.

However, there appears to be a considerable number of cases of non-reversibility in golden-headed lion tamarins (De Vleeschouwer et al., 2000a, but see DeMatteo et al. 2002). However, it

seems that most of the cases of failure to reverse were because the MGA implant wasn't removed, and these implants can continue releasing hormone well beyond the 2-year recommended replacement date. That 2-year date is conservative, calculated to prevent reversal in any individual. Nevertheless, De Vleeschouwer et al. (2004) indicated that never-implanted golden-headed lion tamarins were more likely to reproduce than females that previously received an MGA implant, regardless of whether this was removed or left to expire.

In a few cases implant failure (i.e. unplanned pregnancies) has been reported – although this may have had more to do with under-dosing as commercially available human implants are often cut down in size, which may result in insufficient dosing; or implanting females in the very early stages of pregnancy.

Use during pregnancy: Parenteral progestins during pregnancy could lead to possibility of prolonged gestation, stillbirth, abortion. However, there are numerous anecdotal reports where an implant has been inadvertently inserted early in an unknown pregnancy in primates, with no apparent effect on the pregnancy, and offspring being born normally. Many callitrichid females have been purposefully implanted while pregnant to prevent the postpartum oestrus that occurs in this species. Of these pregnancies 88% resulted in live births and 12 % in abortion or stillbirth.

Use during lactation: Progestins are sometimes prescribed for lactating women and are considered generally safe for nursing infants (AZA WCC).

Use in pre-pubertals or juveniles: Future reproduction was not effected in calves of domestic cows on MGA-feed, but no studies of pre-pubertal treatment with MGA or other progestins have been conducted with other species, so possible long-term effects on fertility are not known (AZA WCC).

Effects on behaviour: Because progestagens can suppress ovulation it can be expected that courtship and mating behaviour will be affected in some way.

In families of golden-headed lion tamarins with non-implanted females at the Royal Zoological Society of Antwerp, proceptive behaviour and mounting behaviour mostly occur around the time of ovulation and therefore have a cyclic pattern (De Vleeschouwer et al., 2000b,c). In families with implanted females this regular cyclic pattern of these behaviours was disrupted. The spread of these behaviours over time became irregular and differed between different groups (De Vleeschouwer et al., 2000b).

This form of contraception allows maintaining of the normal family group in callitrichids where reproductive inhibition is still operational; therefore, just by implanting the breeding female more animals can be kept in a non-breeding situation.

Research at the Durrell Wildlife Conservation Trust indicated that there may be an increased risk of aggression in non-breeding groups of lion tamarins. However, other possible contributing factors such as age of the animals in the group and the group size interact with the effect of the contraception alone. There may be an effect of different types of management systems. Collaborative studies between zoos are necessary to increase the sample sizes (Price, 1998a,b).

In golden-headed lion tamarins females at the Royal Zoological Society of Antwerp, aggression was found to more likely occur in larger groups, in groups with a higher proportion of males and/or the number of sons. This effect was heightened and the thresholds for the effects lowered in groups where all offspring were older than 1 year, regardless of the population control method used (if any) (De Vleeschouwer et al., 2003).

Precautions: In humans long term use of progestins has been linked to osteoporosis. To date, few studies have shown link between progestins treatment and serious health risks in nonhuman primates.(Porton and Dematteo, 2005). There is some indication that contraceptives appear to affect the mood on nonhuman primates females in different individual ways and some females have been reported as more aggressive or "cranky".

Reporting requirements: In order to increase our knowledge of the efficacy of contraception methods in the Callitrichidae family it is recommended that all individuals on contraception be reported to European Group on Zoo Animal Contraception EGZAC (www.egzac.org). EGZAC works in association with the American Association of Zoos and Aquariums Wildlife Contraception Center (AZA WCC).

MGA (melengesterol acetate) implants:

- These implants are now only produced in the US by a company restricted to sell them exclusively in the US. In the EU they are no longer available. It is recommended that the other progestagen implants mentioned below are used instead

- They have been used in *Callimico goeldii, Callithrix argentata, C. geoffroyi, C. jacchus, C. penicillata, C. pygmaea,, C. kuhlii, Leontopithecus rosalia, L. chrysomelas, L. crysopygus, Saguinus bicolor, S. fuscicollis, S. geoffroyi, S. imperator, S. labiatus, S. midas, S. oedipus, S. tripartitus* (DeMatteo, 1997; Van Elsacker et al., 1994; Dutton and Allchurch, 1998).

- Studbook analyses for golden-headed lion tamarins suggested that there may be a higher proportion of stillborn infants born to females post MGA implantation (De Vleeschouwer et al., 2000b).

- MGA was found to cause excessive decidualization of the uterine endometrium in a study of *Callimico*; if this result proves to be generally true, permanent infertility may result, and other progestins would be expected to have the same effects (Asa et al., 1996; Murnane et al., 1996; DeMatteo, 1997). However, many people believe this effect in *Callimico* reverses spontaneously when the progestin treatment is withdrawn. In the common marmoset, endometrial changes appeared to be reversible (Möhle et al., 1999).

- Data from the Durrell Wildlife Conservation Trust suggest that a higher dose is needed for the pied tamarins. Here one rod has been used successfully for contraception in the marmosets but two rods were needed for the pied tamarins (IZVG MGA for callitrichids). Delay reversibility was observed in the black lion tamarin.

Progestagen-containing depot injections [Medroxyprogesterone acetate (MPA) injections (e.g. Depo-Provera®) or proligestrone (Delvosteron®)]:

- They are relatively inexpensive and widely available in the EU and UK.

- MPA is a synthetic derivative of progesterone administered as an acetate salt with anti-estrogenic activity suppressing ovulation.

- It is a fairly non-invasive procedure since it is administered by injection

- Depo-Provera injection can be used to prevent the post-partum oestrus until a suitable longer term implant can be placed or as longer term contraception.

- MPA has been used in *Callimico goeldii*, *L. chrysomelas*, *L. rosalia*, *Saguinus oedipus*, *S. midas*, *S. imperatus*, *S. geoffroyi*, *C. pygmaea*, *C. geoffroyi*, *C. penicillata* (DeMatteo, 1997; K Gold pers. comm.)

- MPA can have a variable length of duration (Porton et al., 1992) and a much higher dose is needed than in Old World primates for efficacy: 20mg/kg body wt of Depo-Provera, effective for approximately 30 days.

- A dose of 50 mg/kg of Delvosteron has been used in a collection for short term contraception (1 or 2 injections three months appart) being effective for approximately 3 months.

- It has been used relatively infrequently with callitrichids.

- The long term use is not recommended since it can have possible deleterious effects on the uterus and mammary tissue.

Norplant (levonorgestrel):

- At the time of writing, Norplant has been withdrawn from the market in several countries because of problems removing the implants in humans and hence its long term safety. However it is still available as the "Jadelle" implant 75mg levonorgestrel (Bayer Schering Pharma) in several European countries, excluding the UK.

- The long thin implant can be administered by injection (procedure comparable to inserting a microchip) but due to the stress sensitivity of callitrichids this still requires a short anaesthesia.

- It is designed for larger animals and the dosage and procedure to be used for callitrichids is therefore not clear.

- It is expected to allow maintenance of the normal family group where reproductive inhibition is still operational; there is at present not enough experience with callitrichids to unambiguously confirm this. It has been used very infrequently in callitrichids. Little can therefore be said about potential behavioural effects, medical side effects, the duration of contraceptive action and the reversibility of this method for this group of primates

- It has been used in *Saguinus oedipus*, *Leontopithecus rosalia*, *L. chrysomelas*, *L. chrysopygus* (DeMatteo, 1997; K Gold pers. comm.; E Price pers. comm. and Dutton and Allchurch 1998; J B Carroll pers. comm.).

- In Jersey, a single rod of Norplant was inserted subcutaneously between the shoulder blades. Reproduction stopped in the three lion tamarin species and no reactions, complications, side effects or rejections of the implants were recorded. Two Jersey cotton-tops that were treated did conceive, which could mean they have lost their implants. There is not enough information to assess its efficacy and there are too few cases to assess duration of contraceptive action.

Implanon (etonogestrel 68mg):

- This single-rod implant containing another synthetic progestin etonogestrel was recently approved for sale in the U.S. It is available in most European countries. Each implant costs about £150.

- It may be effective for as long as 3 years, but replacement every 2 to 2.5 years is a more cautious recommendation.

- The long thin implant can be administered by injection (procedure comparable to inserting a microchip) but due to the stress sensitivity of callitrichids this still requires a short anaesthesia.

- Experience in a few collections recommends that no less than a quarter of a rod should be used. Generally a third or a quarter of the implant has been successfully used in mainly marmosets. Using only a fifth of an implant resulted in a pregnancy in one marmoset.

- The use of Implanon would be recommended in the same circumstances as MGA implants would have been used.

2.4.7.2.4 Immunocontraception

Porcine Zona Pellucida (PZP) vaccine:

Product Information: PZP stimulates the production of antibodies against the receptors for sperm on the zona pellucida of the egg. It is expected not to create the side effects seen with progestagen-containing hormonal contraceptives. This product is available from Dr. Jay Kirkpatrick, Montana, USA (e-mail zoolab@wtp.net to inquire about import to the EU and UK).

Dose: It can be administered by a single injection and is therefore less invasive; however 2–3 injections are necessary for full effect.

Latency to effectiveness: PZP is not effective until after at least 2 injections (typically given at 2–4 week intervals), depending on the species and adjuvant. There must be a minimum 2 week interval after the last injection before the male is placed with the female (AZA WCC).

Oestrous cycles during contraceptive treatment: PZP should not suppress oestrous cycles.

Duration and efficacy and reversibility: So far it has been mostly used in ungulates and carnivores with varying success. If used for a long time (>3 years) it may cause permanent changes in the ovary leading to non-reversible contraception. This may be, among others, species and dosage dependant (Sainsbury, 1996; DeMatteo, 1997).

It has been used very infrequently in *Callimico goeldii*, *Saguinus oedipus*, *Callithrix jacchus* (DeMatteo, 1997; Hearn et al, 1983).

Use during pregnancy: Does not interrupt pregnancy or affect fetus (AZA WCC).

Use during lactation: No known contraindications (AZA WCC).

Use in pre-pubertals or juveniles: PZP-treated prepubertal white-tail deer and feral horses were fertile as adults, but there currently no information for other species.

Effects on behaviour: It does not suppress ovulation and oestrus therefore it can be expected to have less effect on the courtship and mating behaviour. However, in some primates can temporarily suppress oestrus.

Precautions: This method has been rarely used in callitrichids and primates in general. Little can therefore be said about potential behavioural effects, medical side effects, duration of contraception and the reversibility of this method for this group of primates. PZP can cause depletion of oocytes and in some primates it ca cause temporary cessation of oestrous cycles; however, further studies are necessary to prove or disprove the above mentioned expectations/assumptions.

Reporting requirements: In order to increase our knowledge of the efficacy of contraception methods in the Callitrichidae family it is recommended that all individuals on contraception be reported to the European Group on Zoo Animal Contraception EGZAC (www.egzac.org). EGZAC works in association with the American Association of Zoos and Aquariums Wildlife Contraception Center (AZA WCC). Additionally, all institutions using PZP must submit a separate form obtained from Kim Frank at zoolab@wtp.net.

2.4.7.2.5 Intra-uterine devices (IUD)

Due to the very small size of callitrichid reproductive tracts these methods are not practical for this group of primates.

2.4.7.2.6 Termination of early pregnancy by regular prostaglandin injections

- Commonly used in laboratory callitrichids
- Maintains oestrus/sexual behaviour
- Requires monthly injections and therefore monthly capture
- Because urine samples need be collected regularly to determine ovulation and the best time for injection, and because animals need to be captured each month, this makes this a less practical method for zoos. There are also welfare implications from catching the animals so frequently.
- Ethical considerations concerning termination of pregnancy
- Commonly used in colonies kept for scientific purposes (e.g. *Callithrix jacchus* Summer et al., 1985; *Callimico goeldii* Pryce et al., 1993:) also tried in *Leontopithecus rosalia* (Monfort et al., 1996).

2.4.7.2.7 Surgical methods of contraception

Vasectomy/tubal ligation/hysterectomy
- Sexual hormone levels and cycles remain intact and sexual behaviour is therefore not affected.
- Simple surgical technique.
- Although some vasectomies can be reversed, it should be considered non-reversible.
- For permanent contraception, vasectomy/tubal ligation/hysterectomy are to be recommended above the long-term use of any of the other contraceptive methods because there is less chance for negative side effects.

Castration and ovariectomy/ovariohystorectomy
- The sexual hormone levels and cycles are affected and therefore sexual behaviour is affected.
- Simple surgical technique.
- It is non-reversible.
- Sometimes indicated for medical and animal welfare reasons such as reproductive tract tumours, endometrititis and pyometras, repeated c-sections, diabetes mellitus, severe spondylosis, etc

- Castration and ovariectomy should be avoided because the effects on the social and sexual behaviour of the animals. Because these methods are irreversible they should only be applied after recommendation from the coordinator and studbook keeper or following veterinary advice.

Reporting requirements: In order to increase our knowledge of the efficacy of contraception methods in the Callitrichidae family it is recommended that all individuals on contraception be reported to the European Group on Zoo Animal Contraception EGZAC (www.egzac.org). EGZAC works in association with the American Association of Zoos and Aquariums Wildlife Contraception Center (AZA WCC).

2.4.7.2.8   Euthanasia

Because at the moment there is no alternative population control method available which does not have potential or certain negative effects on the animal's welfare, and because euthanasia allows the full range of natural behaviours to be experienced by the members of a family group, euthanasia should be offered as one of the options for population control for those institution that are legally able to do so, and feel ethically sufficiently comfortable with doing so. Possible arguments pro and contra euthanasia can be found in the Appendix (section 24.7.4).

Institutions which have a breeding pair of European Breeding Programme (EEP) callitrichids could be given permission to continue breeding after the studbook keeper has recommended to stop breeding, if they prefer to euthanase surplus offspring rather than use one of the other population control methods.

The studbook keeper needs to advise the institution if there is a change in the need for breeding control in that group.

Please note:
In the case of lion tamarins (*Leontopithecus* sp.) and pied tamarins (*Saguinus bicolor*) (which belong to ICMBio (Institute Chico Mendes for Biodiversity Conservation of the Brazilian Ministry of the Environment)) euthanasia cannot be offered as a management tool under any form unless ICMBio and the International Committee for the Conservation and Management of the Lion Tamarins give the studbook keeper explicit permission to do so.
Euthanasia for population control reasons is illegal in some European countries

2.4.7.3   Summary

1.   At the moment there is no single "right" method for population control in callitrichids. Every currently known procedure has its pros and cons. Because each situation is different, we recommend that for every individual case, the species co-ordinator and the institution together decide on the best mode of action for that group of animals.

2.   For permanent contraception, vasectomy/tubal ligation/hysterectomy are to be recommended above the long-term use of any of the other contraceptive methods because there is less chance for negative side effects. Castration and ovariectomy should be avoided because the effects on the social and sexual behaviour of the animals. Because these methods are irreversible they should only be applied after recommendation from the coordinator and studbook keeper or following veterinary advice.

3.   For non-permanent contraception GnRH agonists and progestagen implants are considered the safest reversible contraceptives. MGA implants are no longer available in the EU.

For many of the Callitrichidae, however there is little detailed and sequential information on the possible physical, physiological and behavioural effects of any of these contraceptive methods, nor on the reversibility of these effects.

Both studbook keepers and individual institutions should do everything within their power to gather as much information as possible on both the individual that is contracepted and on the other members of the social group (see research recommendations below). That way, possible negative effects on individual species can be detected as soon as possible. Any results/feedback should be sent to EGZAC (www.egzac.com) so that further recommendations on callitrichid contraception can be issued.

4.   When other, so far less frequently used, contraceptive methods are tested (e.g. deslorelin, levonorgestrel, etonogestrel or Depo-provera), both studbook keepers and individual institutions should do everything within their power to gather as much information as possible on both the individual that is contracepted and on the other members of the social group (see research recommendations below)

5.   All encouragement should be given to the development of novel population control methods with high rates of reversibility and fewer side effects.

6.   Intra-uterine devices, castration and ovariectomy should not be used for callitrichids.

7.   Because at the moment there is no alternative population control method available which does not have potential or certain negative effects on the animal's welfare, and because euthanasia allows the full range of natural behaviours to be experienced by the members of a family group, euthanasia can be offered as one of the options for population control for those institution that are legally able to do so, and feel ethically sufficiently comfortable with doing so. This should be allowed under the following conditions only:

7.1.   In the case of lion tamarins (*Leontopithecus sp.)* and pied tamarins (*Saguinus b. bicolor*) (which belong to ICMBio (Institute Chico Mendes for Biodiversity Conservation of the Brazilian Ministry of the Environment)) euthanasia cannot be offered as a management tool under any form unless ICMBio and the International Committee for the Conservation and Management of the Lion Tamarins give the studbook keeper explicit permission to do so.

7.2.   Institutions which have a breeding pair of EEP callitrichids can be given the permission to continue breeding after the studbook keeper has recommended to stop breeding, if they prefer to commit to euthanase surplus offspring rather than use one of the other population control methods.

The studbook keeper will advise the institution if there is a change in the need for breeding control in that group.

8.   The following data analyses, monitoring actions and research projects should be carried out as soon as possible. Studbook keepers and co-ordinators should carefully analyse their studbooks with regard to the effects of ALL population control methods (reversibility, physical and medical side effects, stability of groups, behavioural effects, survival of infants etc). If necessary, research projects should be set up to look at these aspects more closely.

A protocol should be drawn up regarding the collection of urine and faeces and the opportunistic application of ultrasound techniques for reproductive monitoring of females (pre- and post-contraception) in as many zoos as possible and for as many species and contraceptive methods as possible in order to solve questions such as:

What is the best moment during the oestrus cycle of the female for implantation of a contraceptive?

What is the effect of the contraceptive method on the reproductive cycle of the female, does the female start cycling again after contraception has stopped and if so when?

What are the effects of the contraceptive method on the uterine and ovarian structures?

For EEP species individual zoos should contact their EEP coordinators for addresses to where the samples should be sent for analyses.

Research should be carried out regarding the behavioural and physiological consequences of life in a unisex group

2.4.7.4   APPENDIX: Possible arguments for and against euthanasia

Possible arguments for euthanasia

1. For welfare reasons, animals in captivity should be able to perform as many of their natural behaviours as possible. Because the very nature of the captive environment in itself already eliminates and/or influences a proportion of the natural behaviour (such as ranging behaviour, predator avoidance behaviour and much of the foraging behaviour) it is important that as many individuals as possible get to practise all the behaviour categories that can be performed in captivity. This includes courtship, mating and infant rearing behaviour.

2. For both conservation and education purposes, callitrichids should be shown to the public in a way which is as close to life in the wild as possible so that they can be a living testimony of their "true story". This implies showing the public family groups with infants. For callitrichids in general, infant care is a very important aspect of their social life, not just for the breeding pair but also for all the siblings.

3. While trying to achieve a partnership between conservation and education, it is necessary to ensure that goals and actions necessary from a conservation point of view do not compromise educational goals and vica versa. For example, while population control is necessary (see introduction), we must attempt to achieve this while not compromising the educational message to the public. On the other hand, we must make sure that we are not too afraid to implement essential population management actions simply because of fear of negative PR. After all, providing the public with a clear and honest explanation of what we are trying to do and why, will often counteract those negative vibrations.

Experience has shown already shown that it is possible to have a serious euthanasia policy in a zoo – provided that one is always very open about it, never hides it and uses every opportunity to tell the press and the visitors the reason for using euthanasia as a method for population control. It is crucial to understand – and to make people understand – that not accepting euthanasia may lead to a decrease in animal welfare caused by the lack of opportunity to perform natural behaviour.

4. By euthanasing surplus offspring when they are evicted from the group, or when they are at an age when one would normally expect them to emigrate from the group (i.e. the older animals) one respects natural group dynamics.

5. By not contracepting the breeding female one avoids the risk of possible negative side effects and/or non-reversibility of the contraception. The latter is especially important in case disaster strikes the offspring of an important breeding pair.

6. One can not, and should not, force any institution to use euthanasia as a management tool. One can however, under strict guidelines, offer it as one of the possible tools for population control (with its own plusses and minuses, just like any other method) to those institutions which feel they are ethically comfortable with euthanasia and which are legally able to perform it.

7. Euthanasia can be a highly selective and efficient management tool. One can carefully control which animal should be euthanased, why and when. It may furthermore prevent surplus animals from ending up in sub-optimal housing conditions.

Possible arguments against euthanasia:

1. The euthanased animal would not have existed (and be killed) were it not for the "enrichment" of the others in the group.

2. We do not fully understand the social dynamics of wild callitrichids. For example:

What proportion of wild callitrichids get to breed during their lifetime? (it is highly unlikely that every callitrichid surviving to adulthood will get the opportunity to breed)
How long does a breeding callitrichid remain in a breeding position? (captive females probably start breeding earlier and breed for longer)

What is the duration of unisex groups in the wild?

Captive females most likely have higher reproductive outputs (mostly more litters per year) – is this physically detrimental to the female and does this tell the "true story"?

3. We tell the public that these endangered animals need saving but at the same time, we euthanase some of them. This may give a confusing PR message. We may be seriously underestimating the opposition to the concept of euthanasia. In many countries, cultures and minds of people, euthanasia is still "taboo".

4. If one waits to euthanase animals until their expulsion from the group, there is a risk of the animal suffering during the eviction (although this is also the case in the wild).   Close monitoring would be required.

5. Pregnancy and birth hold risks such as nutritional and energetic costs for the female (exhaustion etc.), illness and death. Contraception may be a better alternative to euthanasia.

6. Institutions that feel that euthanasia for this reason is unethical may object to any of "their" animals being sent to institutions that practise it (because it means that some offspring from these animals may end up being euthanased).

7. Humans deciding which animals should be removed from the group may result in artificial selection. Do we know enough about the group dynamics in the wild to decided which animals should be removed from the group and when? On the other hand, we are now faced with similar decisions when animals are taken out of the group to start a new breeding group elsewhere.

2.5   Environmental enrichment

2.5.1   Introduction

Primates come in all shapes and sizes and strengths. To enrich a gorilla's life in captivity can be quite expensive, but this is not the case with marmosets and tamarins. Of all the primate groups that are kept in captivity, the callitrichids are perhaps the easiest to provide with a highly stimulating environment. No matter what the budget or the size of the enclosure, there can be no excuse for the available space and husbandry techniques failing to provide enrichment.

Pied tamarins (*Saguinus bicolor*) investigating a rotten log.

2.5.2   What is enrichment?

Enrichment can be described as any change in an animal's life that has a stimulating and beneficial effect.   It is important to consider that there may be forms of enrichment that provide stressful stimuli but that may in fact confer benefits, either immediately or in the future, as well as more closely mimicking the natural environment and prompting behavioural responses that would be normal in the wild. Some behaviours that occur in response to perceived threats, for example, may be necessary for mental fitness, and indeed short acute stress may be needed to provide a healthy immune system. It can also promote positive social relationships (e.g. Chamove and Moodie, 1990). In another example, if groups or their descendents may be reintroduced to the wild, predator avoidance training may be an important part of management.

2.5.3   What is the aim of enrichment?

Enrichment has several aims:

- To stimulate natural behaviour
- To promote development of mental and physical skills by creating new stimuli, challenges and difficulties
- To avoid the development of abnormal behaviour

In other words, the aim of enrichment is to enhance and maintain both mental and physical wellbeing by maintaining a behavioural repertoire in a given species that is as full as possible, within ethical constraints.

2.5.4 Why is enrichment important?

- Animals that do not live in an enriched environment will become stressed and then ill. Psychological and physical wellbeing are paramount to the health of an animal. Social animals in captivity tend to interact too much, leading to problems, While it seems counterintuitive that social primates could socialise too much, this is the biggest cause of problems in captivity: callitrichids in the wild spend up to half their day foraging (see Table 2.5.4-1); in captivity this figure is usually reduced significantly, leading to unnaturally high levels of social interactions, stress and ill health.

Table 2.5.4-1: Feeding/foraging times for wild callitrichids.

Species	% time feeding/ foraging	Reference
M. argentatus	39	Veracini, 1998
M. humeralifer	47	Ferrari and Rylands, 1994; Ferrari and Digby, 1996
C. flaviceps	37	Ferrari and Rylands, 1994; Ferrari and Digby, 1996
C. jacchus	43	Digby and Barreto, 1996 ; Ferrari and Digby, 1996
L. rosalia	34–41	Dietz et al, 1997 ; Peres, 1989
L. chrysopygus	49	Albernaz, 1997
L. chrysomelas	40	Rylands, 1989
S. fuscicollis	26–40	Garber, 1993; Lopes and Ferrari, 1994
S. mystax	27–39	Garber, 1993
S. nigricollis	49	de la Torre et al., 1995
S. oedipus	32	Savage, 1990
S. bicolor	24	Egler, 1992

- There may be seasonal differences in the need to provide enrichment: in temperate climes where animals have outside as well as inside areas, winter has the obvious effect of confining animals indoors due to poor weather, and there are few insects and fruits naturally available. Inside areas tend to provide a far less enriched environment and this, along with closer proximity and thus probably higher levels of social interaction, can lead to increased stress levels. A comparison of cortisol in three callitrichid species showed that baseline levels were higher in the winter than in the summer (McCallister, 2005).

- Neural networks during development of the brain are significantly different in animals raised in impoverished environments to that of enriched stimulating ones, and there is also evidence that a lack of stimulation leads to a decline in neural networks in impoverished environments.

- Preparation for release back into the wild means that behaviour that may only be rarely expressed in captivity needs to be stimulated. For example, captive animals have been taken by predators after release into the wild (e.g. Valladares-Padua et al., 2000) as they are much less reluctant than wild-born animals to descend to the ground, and may be unfamiliar with certain classes of predators as a result of lack of exposure. So it is important for a species to retain behavioural fitness, which may deteriorate with successive generations in captivity. Stimulating predator vigilance behaviour is a form of enrichment and will retain important wild behaviours. Obviously this could have ethical constraints as stressful stimuli to animals in a captive environment may be deemed unacceptable.

- Research in captivity requires animals that behave naturally. If captive marmosets and tamarins are not kept in an enriched environment that in some ways mimics the wild, they will not be able to exhibit the majority of their wild behavioural repertoire. Much behavioural research in captivity will then be pointless.

2.5.5   What if we don't enrich?

A lack of enrichment can lead to stress; McCallister (2005) found that callitrichids in a free-ranging environment tended to have lower cortisol levels than those living in cages, though the effects were not statistically significant. Chronically heightened cortisol levels are known to depress the immune system leading to the development of disease. Ultimately, this could be a cause of death.

Signs that a callitrichid's environment is inadequate include:
- Stereotypical behaviour
- Passivity/lack of responsiveness
- Aggression
- Aimless locomotion
- Loss of interest in play
- Loss of sexual interest
- Self-harm
- Eating disorders e.g. coprophagy

2.5.6   Caution

Callitrichids are often extremely sensitive. Their disposition is to be alert to predators as they have many in the wild. The use of enrichment must not cause chronic stress. While brief periods of acute stress can be beneficial to immune function, chronic stress will cause immune function failure.

The aim is to mimic a natural existence to improve health and wellbeing and reduce stress caused by the captive environment; too much or too frequent alteration in their environment can be detrimental. As callitrichids use many different forms of communication – visual, vocal, olfactory – there is great potential to use many different enrichment techniques, but overuse of any or all could also be a cause of stress.

2.5.7   Callitrichid ecology and foraging behaviour: implications for enrichment

The intelligence and inquisitive nature of callitrichids, and the fact that they use many parts of the forest environment that they have evolved in, makes enrichment both easy and cheap.

The evolutionary dwarfism that callitrichids have undergone means they can use a huge variety of substrates. They are able to move along very thin, flexible supports and also, as they have claws instead of nails on their digits, cling to large rough tree trunks. Providing the opportunity to move around on all these different types of support and substrate is a basic requirement of enclosure design as it enables individuals to develop balance and coordination and the ability to judge distance and use a variety of different methods of locomotion, including climbing and leaping. Natural branches also provide an abrasive surface to stop claws becoming overgrown.

One-third to one-half of a wild callitrichid's day is spent feeding and foraging. *Leontopithecus* and marmoset species tend to spend more time than *Saguinus* foraging (see Table 1.6.2-1). One of the primary needs in captivity is therefore to increase foraging behaviour and much enrichment is based on this.

Insects are an important component of the diet of all callitrichids, and they forage for invertebrate prey in foliage, tree crowns, leaf litter accumulations and very occasionally on the forest floor. There is thus the potential to provide enrichment opportunities at all levels.

Free-ranging silvery marmoset in Jersey feeding on natural tree

The fact that different callitrichids forage in different ways also needs to be taken into account. The various genera have evolved to fit many different ecological niches, and even within a genus there are differences in foraging techniques. We need to consider the natural foraging styles of each species in developing appropriate enrichment techniques.

Marmosets have dentition that enables them to gouge holes in trees to extract gum, while although tamarins eat gum, they have to take advantage of ready-made holes. Marmosets also use gleaning to gather insects from foliage, and a sit-and-pounce technique for catching prey. The vast majority of a marmoset's foraging time may be spent scanning for insects rather than in the active manipulative foraging that tamarins use.

Lion tamarins have long hands that they can use to reach into holes and into the deep centres of plants such as bromeliads. This behaviour is frequently seen in captivity as lion tamarins probe every conceivable nook and cranny that they can in an enclosure. Lion tamarins will automatically investigate a hole with their hands when presented with the opportunity and frequently do so while looking in a different direction. Other species, such as cotton-top tamarins, may be much more reluctant to reach into holes when they can't see what is in them (E. Price, pers. comm.).

Leontopithecus seem to use higher levels of the forest than other tamarins. Their extended digits could be an adaptation specifically for foraging in holes and the leaf axes of bromeliads. They need less disturbed forest with more tree holes and bromeliads. Hanging plants with their associated gaps and crevices are easily provided and will stimulate the natural foraging behaviour of lion tamarins.

Saguinus species use many different foraging techniques. Body size differences may be of fundamental importance, and the use of lower levels in the forest may aid in hunting for insects.

2.5.8   An enriched environment

Most enrichment tends to be food-based and aimed at increasing the proportion of their active period that the animals spend foraging. With a high-quality complex environment, even a small space can provide much of the enrichment a callitrichid needs without the need for artificial devices.

An outdoor enclosure for callitrichids in Jersey, showing natural trees, cover provided by climbers and other fast-growing plants, roping to provide travel routes, and rotting perching providing foraging opportunities.

Enrichment should therefore start with good enclosure design. Size isn't everything: quality is better than quantity. An enclosure should be designed as if it were a small chunk of rainforest.

Complex branching/rope systems provide opportunities to move on a wide variety of fixed and mobile substrates, mimicking the structure of a forest.

Planting is the easiest way to create a semi-natural environment for callitrichid species where they can express their natural array of behaviours with little interference from staff. In tropical climates this can be done easily with plants endemic to the region the species comes from. Small fruiting or flowering trees, whilst taking a while to establish, will provide sensory stimulation for the animals – not only by providing fruit/flowers but also by encouraging insects into the enclosure which the animals can then forage on naturally.

For new enclosures in temperate climates the best plants are evergreen shrubs and trees and fast growing climbers; ivy, *Hedera* spp., is ideal. As well as providing substrates to forage in it also gives cover for these naturally shy animals, and in more tropical climates it also has the advantage of providing shade.

Large pieces of wood in the enclosures will provide natural perching initially but are also a support for climbing plants to grow up. In addition, as the wood decays, it will provide a source of insects which the animals will have to forage for as they would in the wild. A simple piece of rotting log will provide great enrichment as it is investigated and pulled apart.

If ground space is limited or cannot be planted, hanging baskets can be used, either suspended from the cage roof or attached to large branches/perching. Filling these baskets with climbers, trailing plants, herbs and flowers can turn the most basic enclosure into a more naturalistic environment which can then provide the animals with sensory stimulation and enrichment.

Emperor tamarin foraging in ivy.

2.5.9   Artificial devices

Simple foraging devices are often useful in indoor areas during periods of bad weather or in climates which are less than ideal. Enrichment devices need to be cheap to make, quick to use and

easily serviced within the husbandry routine, and ideally reusable. If too elaborate and time-consuming, they won't be used and will slip from the daily routine in a busy animal carer's daily schedule.

Providing several different enrichment items in enclosures allows members of the groups to forage independently and therefore relieves tension and prevents fights over food.

Most methods are aimed at providing food in a more naturalistic way, increasing foraging and handling time. Techniques include:

- Hanging rotten logs/creeper-covered logs. These will maintain their own populations of insects and grubs, or can be sprinkled with treats.

- Hanging baskets/plastic crates. These can be filled with substrates such as straw, hay, wood wool or wood shavings and hung up in enclosures to create foraging areas. Again, sprinkling a few insects into the substrate will encourage natural feeding behaviours from the animals.

- Gum feeding devices. Several possibilities are available; a "gum-tree" (McGrew et al., 1986) can be constructed (these stimulate the natural behaviour of marmosets, requiring them to gnaw holes into the wood before the gum can be extracted), or more simple methods can be used. Gum tends to be preferred in liquid form rather than as solid chunks (Herron et al., 2001), and will be consumed by most species, though it is particularly liked by marmosets and as they are obligate gum feeders it should be provided daily for these species.

Wooden insect house being investigated by pied tamarin.
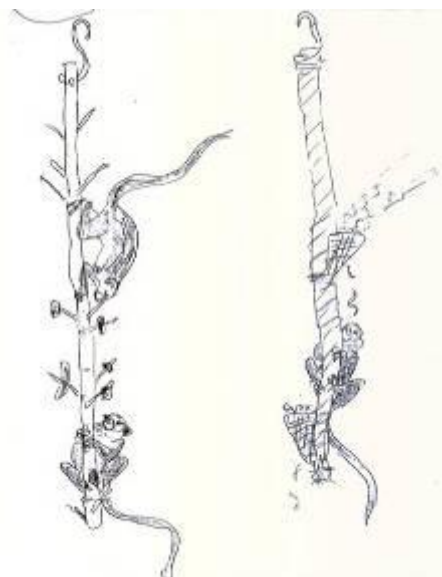
Methods of attaching food to mobile structures such as hanging canes or ropes.

- Cane or rope "kebabs", with fruit attached, so that the animals have to jump on to a moving substrate in order to reach the food.

- Insect houses. These can be easily constructed and filled with bamboo pieces. These encourage self-sustaining insect populations into the animals' enclosures which will in turn provide enrichment as the monkeys will forage constantly in and around the boxes looking for bugs.

Coconut shell feeder.

Pied tamarin inspecting a log; mealworms or other treats are hidden in holes drilled into the wood.
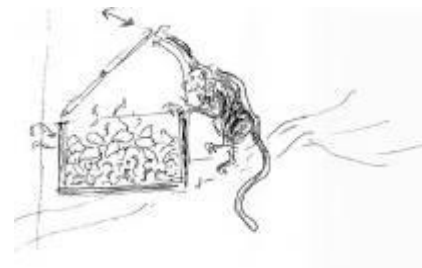
Puzzle box feeder.

- Logs or coconuts with large holes drilled into them. These are also a cheap but effective enrichment device. Insects can be introduced into the holes and will be released slowly, thus keeping the animals' attention for longer. Alternatively honey can be put into the holes, encouraging the animals to manipulate the enrichment device and think up ways of retrieving the treat.

- Puzzle feeders, e.g. boxes with lids.

A variety of food items can be used in these devices; insects are ideal. However, mealworms should not be used too much as their calcium-phosphorous ratio is not good. Care should also be taken not to use sweet foods such as dried fruit or honey too often as it can result in tooth abscesses. Callimico are particularly susceptible to these.

It is important that any string or cord used in the enclosures is not loose, making it possible for it to form a tourniquet around a limb – thick rope or chain is preferable.

2.5.10 Other forms of enrichment

While much enrichment is foraging-based, other forms of enrichment should not be ignored. A sprinkler system can mimic a rain shower and can encourage invertebrates into the enclosure during periods of dry weather when the enclosure may otherwise become quite bare. As noted previously, brief exposure to simulated predators can prompt rarely-seen behaviours and increase social cohesion.

Grooming platforms can be placed in sunny spots or under heat lamps.

Simple platforms and shelters can have many benefits – marmosets and tamarins need the option to sleep in nest holes or rest in safe areas in the middle of the day. Clumps of lianas are often used by callitrichids as roosting spots (Roosmalen, 1981), and Leontopithecus use tree holes for daily roosting activities.

Conduit tubing cut into sections provides shelter and privacy for the animals at very little cost. It can diffuse tension within groups as it allows cagemates a place to retreat to during conflict. It also gives nervous animals a place to hide when animal staff are servicing the enclosure.

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Pied tamarin with young on back using conduit tubing.

It is also important to have resting platforms in high positions in an enclosure so animals can relax with a feeling of security – for this reason enclosures should be made as high as possible. Platforms also provide the opportunity for group members to groom one another, which helps in group cohesion. Such grooming is often observed on broad branches in the wild.

Olfactory and acoustic communication is also important for callitrichids. For example, occasional scent-based enrichment can be introduced, for example by putting a branch marked by another group into the enclosure. Aromatic plant scents such as lavender and scented mayweed can be tried.

2.5.11 Things to avoid

It is important to make sure that the background noise level is not too loud as it may cause chronic stress. Laboratory guidelines on acceptable noise levels could be followed here, e.g. those imposed by the UK government (see United Kingdom Home Office, 1989).

It is also important to avoid over-cleaning so that scents communicating social information are not completely removed from the enclosure.

Social enrichment – the need for companionship – is vital. As all callitrichids are social animals they should never be kept solitary unless in extreme situations (such as abnormally aggressive behaviour). See chapter 2.3 on social structure.

2.6 Capture, handling and transport

2.6.1 General principles

The callitrichids can be said to be of a generally nervous disposition. This is probably a result of being highly tuned to avoid predators in the wild. When keeping marmosets and tamarins in captivity this should be taken into account during all aspects of husbandry, and possible or perceived threats should be eliminated as far as possible.

Handling should therefore not be part of any routine management. The capture of an animal should be carried out only by an experienced carer and only when absolutely necessary, as this will probably be one of the most stressful, and potentially harmful, experiences for a captive animal. Poor capture and handling can lead to tooth breakage or loss, limb fractures, and broken fingers and claws, all of which are avoidable.

Animals have been known to die during or just after capture and handling so methods which minimize any stress to the animal must be employed whenever possible.

It is also important to remember that the capture of an animal affects not only the animal being caught but also all those in the vicinity; therefore frequent capture and handling can create chronic stress and have a negative impact on the health of all animals nearby. Recurrent capture and handling will build a negative relationship between keepers and the animals they are working with, making the daily checks that are needed for these animals difficult.

The monkeys should not of course be pets, but should have neutral relationships with their carers. This makes management easier and it is likely that the animals will be healthier.

When and when not to capture

The capture and handling of any animal should only be done if there is no alternative, and the decision should only be taken together by an experienced carer/ curator and vet, for example if the animal is suffering ill health or in extreme situations where an animal needs to be immediately removed from an area.

Although permanent ID marking, including insertion of microchips, tattooing, etc, requires animals to be caught up, it can usually be carried out when a specimen is having another veterinary procedure. Animals should not usually have to be caught and handled for any routine management such as weighing. Callitrichids can easily be trained with treats to sit on scales and be weighed, or to take oral medication, providing the carer has a good relationship with the animal. Relocating animals can also usually be achieved without handling, e.g. by transporting them in a mesh tunnel or their nestbox.

2.6.2 Methods of catching

Tunnel

Ideally, enclosures should contain a specific catch-up area – a tunnel that the animals run through daily works best, but a portable tunnel can also be very useful and can be used in multiple enclosures. A feed dish placed within the catch-up tunnel will get the animals used to using the tunnel on a daily basis. As for the vast majority of the time the animals will have no negative association with the tunnel, they will enter it freely, and on the infrequent occasions when an animal is caught by use of the tunnel it will not generally associate the tunnel with a trip to the vet centre.

The catch-up tunnel can be made entirely of metal mesh with a door at one end; the tunnel can be attached to the cage front with bungee cords, allowing for easy removal.

Tunnel attached to front of cage, with string attached to door to allow it to be shut remotely.

Wooden comb used to divide, close off and move animals

Once the animal has entered the tunnel the door can be shut remotely from the outside using a piece of string or wire. Alternatively the tunnel can be placed at the entrance/exit point between two areas of an enclosure that the animal uses daily so the tunnel is incorporated into the cage furnishings.

A wire or wooden comb that can be slid between the mesh can be used to secure the tunnel entrance and sheets or blankets can be used to cover the trap, giving the animal a dark environment that should minimize any stressful impact.

Two golden lion tamarins trapped and separated within a single portable tunnel placed at the exit from their inside area.

This method can also be employed when catching up groups, although it may take more time. It may also prove to be advantageous as either the entire group (when using a large catch-up tunnel) or several members at a time can be caught, limiting the group's exposure to stress. If a net was used to capture a group, by the time it came to the last animal's turn to be caught the individual would be highly stressed having seen its family netted, and the health risks and the risks of injury during capture would be significantly higher.

Separation of individuals within the tunnel can be accomplished using combs.

A pillowcase placed over the end of the tunnel allows monkeys to be removed without handling.

Removing the animal from the trap is simple: open the door, leaving the animal secured behind a comb, and place a pillowcase or similar around the entrance. Then, using the combs, push the monkey down towards the pillowcase. Once the animal has entered, the pillowcase can be closed and held.

A pillow case is ideal as it allows the keeper to hold the monkey in the correct way whilst it is still being contained and allows the pillow case to be peeled back so that only small parts of the animal can be exposed (i.e. head for anaesthesia mask or leg/back for medical injections).

Only when in the vet centre is the animal handled.

Nestbox

In the unlikely event the monkey does not enter the trap, the next best method is to trap it in its nestbox. Often if a keeper is in the monkey's enclosure he/she can encourage it to enter the nestbox with treats or gentle pushing, or if the capture is planned for early morning or late evening the door can simply be shut once the animals have gone to sleep. Once secured in the nestbox the animal can be transported safely. Removing the monkey from the nestbox can be accomplished by running the animal into a mesh catch-up tunnel and then into a pillowcase as described previously.

If this procedure fails it may be necessary to handle the animal to remove it from the box. A pillowcase can be placed over a gloved hand, which the keeper then slides into the box. The keeper grasps the monkey and then pulls it out, covering the animal with the pillowcase as the hand is removed from the box. This method is usually the more difficult as the tamarin can press its back into the corner of the box, thus not allowing the keeper to obtain a safe grip on the animal. The animal will also use this position to bite the gloved hand trying to capture it, which can lead to tooth injuries.
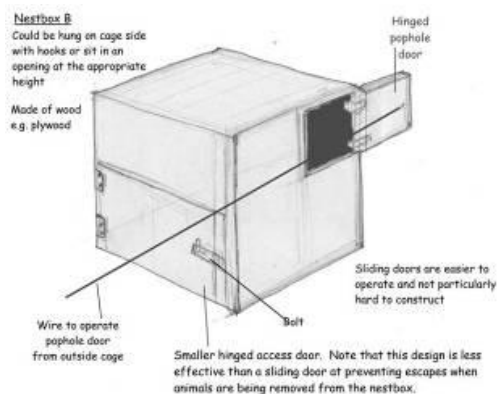
Using a nest box to capture a monkey.

The net

Capturing an animal with a net should be the last resort and undertaken only by a trained keeper. This method of capture can be extremely stressful for the animals involved and can often result in serious injuries to the animal. If a net is to be used the process should be as quick as possible and involve little or no chasing of the animal around an enclosure, and capture in the smallest enclosure possible is recommended. If a net is used it should be a light, easy-to-wield hoop. This should be fitted with a cloth bag rather than mesh, as the use of mesh bags can result in injury to trapped limbs.

The mouth of the net should be at least 30 cm diameter, and ideally should be padded around the perimeter.

When using the net method for catching an animal it is important to ensure that all other animals occupying the cage are separated off (either shut outside or separated into another area of the cage) to minimize the chance of them witnessing the capture and being stressed by the procedure. It may also be a good idea to have any other animals in the vicinity who will be able to see the process shut away in an area which does not allow them to see the catch-up.

With the tunnel method, as it is a minimal stress technique, it is not necessary to separate or shut away nearby animals.

Cloth bag fitted to padded hoop (left); leather or suede gloves for handling (right).

2.6.3   Handling

Handling should only be undertaken by an experienced carer. Damage is often caused during rough or inappropriate handling. The most common injury is that of teeth breakage, mainly canines. Injuries like this can lead to serious chronic long-term health issues. In extreme cases animals can die during handling.

The very fact of handling is extremely stressful and can be the precursor to a period of illness. Handling should be avoided before an animal is exported if possible as the added stress of travelling can cause serious harm.

All handling should occur outside and away from the enclosure the animal occupies, e.g. in a vet centre or another safe enclosed place. If animals are handled by their carers regularly within the enclosure, the relationship between the carer and the monkeys will break down. A negative relationship will make routine observation and other husbandry very difficult.

Whenever possible the handler should not let the animal that is being held see them. Callitrichids have very long memories!

The best grip to have is around the back just underneath the animal's armpits and can usually be achieved with only one hand. This allows the other hand to be free to peel back the pillowcase to present parts of the animal for veterinary inspection. The grip should not be too tight and if the animal bites into the glove the hand should *not* be pulled away as this will damage teeth – the glove should be removed when the animal relaxes its bite.

See section 2.6.5 for safety issues during capture and handling.

2.6.4   Transportation

Transport should be a careful process in which as much as possible is done to minimize stress. Try to avoid handling before transport. It is also important to make the transfer as fluent as possible with as few changes as possible. The same nest box and diet before, during and after transport will reduce stress considerably. Always double-check with the receiving institution about times and connections of transport.

ID

All individuals to be transported should have a microchip or other recommended means of permanent identification (see Section 2.1). The transponder chip number should be known by sender and receiver and checked before transport.

Labelling

The identification of receiver, sender and animal(s) should be written on the crate.

Familiar smell

The crate in which the animal will be transported could be placed in the enclosure of the animal for a period before transport to give the monkeys the opportunity to become familiar with the crate and to give it the animal's smell. For smell absorption wood should be part of the crate. If this is not possible, add some of the enclosure bedding or put a small scent-marked item of enclosure furniture in the crate just before the animal is put in it.

Diet

During transport the animal should have access to familiar food items with a high water content, such as fruits and cucumber. The transporter should give the animals water if the transport is longer than half a day and/or in a very warm climate, but provide a small water bottle for long journeys just in case. The animal should be preferably accompanied by the prefabricated part of the its diet such as pellets, canned food or porridge, enough for at least two weeks, to ensure that it receives familiar food on arrival in its new surroundings. However by air this might not be possible.

Transport of a whole family

Usually one animal or a pair of animals will be transported, but on rare occasions a whole family unit will be translocated. This is a risky procedure because there is a chance that the occupation of a new territory will result in changes in the social dynamics of the group, and changes in the dominance hierarchy. This could destabilise the group.

The crate

The crate should ideally have two compartments to prevent draughts and to allow movement and seclusion at the choice of the animal. However for air transport one should follow IATA regulations, which allows for only one compartment. Details can be found in the IATA Handbook which is updated annually (see IATA website, www.iata.org). Some countries may also have specific requirements for crates and furnishings.

- The compartments in the crate should be small so the animals cannot fall if there are sudden movements during transport and injure itself. Inside the crate they need some furniture (stick, piece of wood) to hold on to and stabilize themselves.
- The crate should be made out of wood and/or plastics. Metal gets too hot and is too noisy. Cardboard gets wet and is not strong enough. "Sky kennels" are a good option.
- The crate should be well ventilated, but draughts must be avoided.
- It should never be completely dark in the crate.
- Familiar animals should be able to keep in touch by seeing, smelling and hearing each other.
- A familiar pair can be transported together in one crate.
- Unfamiliar animals should be shipped in separate crates.
- Since the crate is small it is advisable to give it some bright colours on the outside to prevent it from getting lost between other larger crates.
- Handles or a bar around the crate should prevent neighbouring crates from closing off the ventilation holes.
- Mesh on the outside of the crate must prevent people from putting objects or fingers in the ventilation holes, as well as stop the animals reaching their arms out.
- One mesh window on the front and one for the inner compartment should allow Customs to see the animal. A burlap (hessian) cover/curtain should close the window on the outside to dim the light and prevent draughts.
- The temperature in the crate should never drop below 15 ^{o}C nor rise above 25 ^{o}C.
- There must be enough substrate (e.g. sawdust or wood chips) in the crate to prevent the animal from sitting in its urine and droppings.
- Woodwool or similar material provides extra security and warmth.
- The size of the crate should be 30 x 30 x 30 cm for a single animal crate and 40 x 40 x 40cm if a pair is transported in one crate.
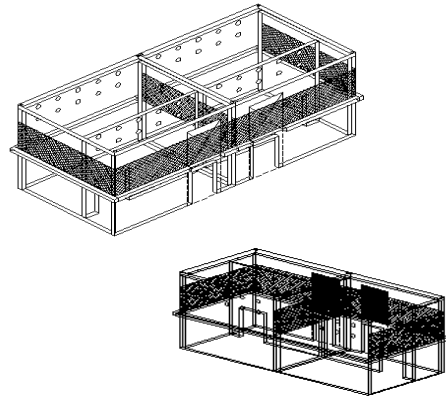
(Left) "Sky kennels" can be used for transport. Note shavings, wood wool, food, water, and fine mesh and hessian covering openings. (Right) Examples of crate design.

Time of transport

In countries of export or import with hot summers or cold winters, spring and autumn are the best times for transport. Otherwise extra care must be given to isolate or ventilate the crate. Ensure that the recipient of the animals knows well in advance of their arrival. Do not leave this for the transporter or carrier.

Medical examinations

Every examination that requires separation from group members and/or handling is highly stressful. It is important, therefore, to minimise handling during and in the weeks after transport.

It is highly advisable to quarantine the newly arrived individual together with its future mate rather than keep it 4–6 weeks in isolation. A complex environment is as important during quarantine as it is before and after quarantine (see Section 2.7.5).

2.6.5 Safety

Safety during handling

As even the smallest callitrichid can inflict deep bites, if handling is required it should always be done with gloves – preferably leather or suede, as if the animal does bite on the glove the material will be soft enough to minimise the risk of tooth damage whilst still preventing the keeper's skin from being broken. This is important as bites from primates carry the risk of disease transmission *both* from the animal to the handler *and* from handler to animal. As non-human primates and humans have a very high phylogenetic relationship there are a number of pathogenic organisms that can be transmitted. The risk may be greater than in handling other animal species.

NB. Marmosets and tamarins can bite through cloth. Surgical gloves do not give any protection against bites. See Section 2.7.3 for further comments on handling animals for veterinary procedures.

Minimizing risk of disease transmission

It is very important for animal as well as human health that steps are taken to prevent direct contact – for example, the herpes simples virus is present in 80% of humans, and is fatal to callitrichids. See veterinary section (2.7.11) for further information.

Health screening of animals for potential pathogens when leaving or entering a collection is a very important part of any health and safety protocol.

As the risk of disease transmission to and from members of the visiting public is very high if contact can be made through an animal enclosure perimeter, it is of the utmost importance that there is a standoff barrier around the front of the enclosure. This will also prevent any member of the public being bitten.

If there is any possibility of free contact between the public and animals, e.g. if monkeys are free-ranging, the situation should be closely monitored so that staff can intervene to prevent direct contact if necessary.

A barrier inhibits any contact between primate and human visitors through a mesh-fronted enclosure.

2.7   Veterinary considerations for health and welfare

2.7.1   Introduction

Before considering disease management in the Callitrichidae, it must be emphasized that the following must be achieved first in order to maintain these animals in good physical and mental conditions:
- proper housing
- proper diet and water supply
- adequate social grouping
- enriched environment
- appropriate mixed species groupings

These aspects of management are covered in previous chapters.

2.7.2   Routine observation

It is essential that the different members of a family or group be checked daily for their appetite and general behaviour. Offering much appreciated items (insects for instance) by hand enables observation of the face and mouth, general condition of the body, quality of hair, wounds,

signs of diarrhoea and signs of pregnancy. If an individual behaves abnormally it is cause for concern and, at the very least, the animal should be monitored closely.

Routine medical programme: faecal samples should be collected once or preferably twice a year in order to look for parasites and the most common pathogenic bacteria. Treatment should be given accordingly.

When the opportunity arises (e.g. if a specimen is handled or anaesthetized for another reason) serum samples should be taken and stored at –20°C or below. This serum bank can be very helpful for further diagnostic procedure (reference, serology etc) and for various research works.

2.7.3   Clinical examination

Signs of diseases are often difficult to recognize in these species but a qualified and experienced keeper will notice specimens exhibiting abnormal behaviour.

The primate must be caught for close examination (see Section 2.6). While this is very stressful, it cannot generally be avoided. If the examination is not urgent, the best time to catch the animals is in the early morning or late evening when they are still in their sleeping box. Examination should be performed as quickly as possible in order to avoid extended stress. The identity of the specimen is recorded (tattoo, microchip) (see Section 2.6). It is also very important to record the weight. The veterinarian may then examine the physically restrained animal paying attention to the oral cavity, the mucosal membranes, lymph nodes, palpation of the abdominal cavity, and the bones and joints.

X-rays and other imaging procedures such as echography, fibroscopy etc. are possible and, if necessary, samples are taken in order to complete the physical examination with laboratory analyses. Screening for pathogens in faeces or swabs and blood profiles are the most commonly performed analyses (see Appendix for the site of venipuncture and for haematological and biochemistry reference values). Some micro-organisms that are shed intermittently (*Salmonella spp*.) or do not survive very long after sampling (*Entamoeba histolytica*) may require special attention. Precautions required by the laboratory must be followed in detail in order to increase the chances of detecting these delicate pathogens (e.g. *Shigella*).

As a result of this examination, complementary analyses, and the medical history of the individual, a diagnosis should be apparent and a treatment initiated as soon as possible.

2.7.4   Treatment

It may be necessary to treat all the family members or indeed the entire collection in case of a contagious disease.

The sick animal may be isolated for prolonged treatment and care. Such a situation is stressful and may lead to the eviction of the individual when reintroduced to the family group. This fact must be kept in mind and the isolated individuals should at least have visual and auditory contact with their relatives whenever possible.

Specific treatment may be given by different routes such as parenteral, local or oral. As a result of their relatively small size (body mass 100–800g) precise calculation of dosage of treatment is very important.

The oral route depends on the appetite of the specimen and injections should be preferred if the monkey is anorexic.

Palatable paediatric treatments for human babies can be very useful for acceptance of oral therapy. Medical training can be used in order to make the animals individually receptive to a syringe with a liquid with or without medication.

Heating and supportive therapy are of utmost importance in these small species with limited reserves. Fluids can easily be given subcutaneously or intraperitoneally, the latter route being highly recommended in case of emergency. Intravenous infusions are possible but difficult to perform and one can try the intra-osseous route (femur). It is sometimes useful to force-feed sick callitrichids with liquid food or food substitutes used for human therapy.

In general, seriously ill animals do not respond well to treatment so the emphasis must be on prevention of disease.

2.7.5 Quarantine

Prior to any animal transfer, the receiving establishment should be provided with a complete historical report for each animal including:
- species and sub-species
- age and sex
- identification
- rearing (hand-rearing or family-rearing)
- social experience
- diet
- medical records

All callitrichids entering a collection should undergo quarantine isolation. The details of such a procedure may sometimes be required in the veterinary import conditions in case of an international transfer. If not otherwise specified by the import requirements, this period must be at least 30 days and different tests must be performed in order to establish the health status of the newly received animal. The following should be done:
- identification check
- weight record
- clinical examination
- faecal test for parasites
- faecal test for bacteria (*Salmonella*, *Shigella*, *Yersinia*, *Campylobacter*)
- treatment when appropriate
- tuberculosis test (see Appendix).

2.7.6 Post-mortem examination

A complete post-mortem examination should be carried out on each dead callitrichid even if the cause of death is already known. This is very important because this provides a check on the presence or absence of concurrent disease that may be relevant for the surviving members of the colony.

Likewise, newly born and dead callitrichids must be necropsied. For obvious management reasons it is very important to differentiate still-born animals (due to infections, nutrition etc) from newborn which are born live and then killed or abandoned by the parents at birth.

Microscopic examination and other tests for parasites, bacteria and even viruses should follow a macroscopic post-mortem examination.

Necropsy should be carried out as soon as possible after death. If there is a delay, the body should be stored in a refrigerator (but not frozen) to reduce autolysis. Following post-mortem examination, relevant tissues should be stored as fixed tissue for future examination. It is also useful to consider storing tissues at −20°C or below. This may allow further diagnostic analyses at a later date and may be useful for research purposes. In the case of those species in breeding programmes, the Species Coordinator should be contacted for special requests regarding tissue and data collection.

It is important that the coordinator routinely receives a copy of the post-mortem report in order to monitor widespread health problems for the species. A post-mortem report should ideally be written in English or at least the mean points should be translated into English. A minimum standard should include following information:

- individual data: species (English and/or scientific name), age, sex, identifiers (transponder, tattoo, etc.), housename, local ID and/or studbook no.
- condition: body condition, weight, contracepted or not
- main findings in gross pathology
- main findings in histopathology
- identified agents (parasites, bacteria, viruses)
- diagnosis incl. cause of death

Specific health problems may occur in some callitrichid species. If special examinations in dead specimens are required or special tissues/organs should be collected, the coordinator has to inform all participating institutions that this should be done (see Section 2.8, Special problems).

For scientific reasons it could be necessary to focus on special examinations or tissues too, e.g. for urogenital tracts of chemically contracepted females (see Section 2.9, Research).

2.7.7   Anaesthesia

Callitrichids are usually anaesthetized by intramuscular injection with ketamine alone or ketamine + a tranquillizer/neuroleptic drug (xylazine, medetomidine, acepromazine, diazepam, etc) or tiletamine + zolazepam (dosages are given in the Appendix to this chapter).

When using ketamine + medetomidine, we are able to reverse medetomidine with atipamézole and then recovery is much quicker.

Prolonged anaesthesia may be achieved with inhalation anaesthetics after induction with an IM anaesthetic drug but gas anaesthesia can also be performed directly with a facial mask or in an induction box. With this kind of anaesthesia, recovery is of very good quality indeed.

2.7.8   Contraception

Breeding programme recommendations sometimes require temporary or permanent suppression of reproduction in some groups. This can be achieved through different techniques such as:

- temporary: a number of different methods (injections, hormonal implants) have been used in callitrichids. See Section 2.4.7.2.3 for further details.
- permanent: ovariectomy, ovariohysterectomy and hysterectomy as well as vasectomy (Morris and David 1993) and castration have already been performed. The surgical techniques are similar to the classical ones for other mammals. For recommendations on procedures to use please see Section 2.4.7.2.7.

The Species Coordinator must be consulted in all cases of temporary or permanent contraception of animals in coordinated breeding programs.

2.7.9   Preventive measures

High standards of hygiene are required in order to avoid the spread of pathogens:
- food: dishes should be cleaned and disinfected daily, perishable fruits and similar items should be stored in a fridge, pellets and other concentrate food should be kept out of reach of rodents, birds, insects and feral cats.
- water: containers should be cleaned and disinfected daily
- enclosures: foot-baths and pest control are needed. The role of transmission of disease by pest species is extremely important in many situations.
- transport cages, bags and nets used for capture should be disinfected after use.

2.7.10   Vaccination

Capturing and vaccinating the animals is a very stressful procedure and vaccination programmes must not be decided without due consideration.

Tetanus and measles are possible vaccinations, as well as rabies in enzootic areas. A *Yersinia pseudotuberculosis* vaccine is also available at the Utrecht University (NL) but its effectiveness is still questionable.

Recommendations on vaccination programmes for primates can be found in Lewis (2000).

2.7.11   Zoonoses

Various pathogens can cause disease in both humans and callitrichids and the risk of transmission between the two groups always exists. Most zoo animals are now captive bred and the risk from exotic pathogens is very low.

Diseases may spread by various methods such as physical contact (bites, scratches, exposure to excreta), ingestion and air transmission. Common sense hygiene measures are vital in order to avoid exposing keepers to these risks, and include:
- frequent hand washing
- wearing specific work clothing
- using disposable gloves in case of handling
- keeping hands away from the face; for this reason, smoking, eating and drinking in animal areas should not be allowed
- all bites and other injuries should be reported, cleaned, disinfected and treated if necessary as soon as possible, according to a protocol set up with a human doctor.

Pregnant female keepers may need to stop working with primates due to these considerations, as well as immuno-suppressed workers.

Similarly, keepers should be monitored since they may shed relevant pathogens.

Yearly tests for faecal bacteria and parasites, throat swabs for *Streptococcus* and *Haemophilus*, and skin-tests for tuberculosis should be considered, but may not be appropriate for all collections. Moreover, sick staff members should not work with primates or prepare food since cold, flu and other viruses could then be passed to the colony.

It should be noted that *Herpes simplex* (common cold sore virus) is fatal to callitrichids. Keepers and other personnel with cold sores should not be allowed to work in callitrichid areas (see Section 2.7.12.6, Nervous system). People other than the relevant zoo staff should not be allowed into callitrichid housing areas. General information on the risk and prevention of primate–primate (including human) disease can be found in Lewis (2000).

2.7.12 Common disorders (brief description, treatment and prophylaxis)

2.7.12.1 Digestive system

Faecal analyses (cytology, Gram coloration, occult blood, parasites, bacterial culture) are of the upmost importance. They help diagnose infectious versus non infectious diseases and guide the first intention treatment.

Bacterial infections: *Salmonella*, *Shigella*, *Campylobacte*r, and *Yersinia* are classically involved in severe enteritis and therapy necessitates antibiotics as well as fluids, gastrointestinal protectorants and even corticosteroids (against toxins). As the faecal-oral route is the common mode of infection, hygiene and sanitation are of utmost importance for other primates and for the keepers. Pseudotuberculosis due to *Yersinia pseudotuberculosis* may cause an acute disease with lethargy and diarrhea or, more commonly, a chronic infection with loss of weight. The post-mortem examination reveals an ulcerative enterocolitis and the presence of numerous small necrotic foci in the mesenteric lymph nodes, and often most noticeably in the liver and spleen. It is not possible to macroscopically differentiate the infections caused by *Y. pseudotuberculosis* from *Y. enterocolitica* and from tuberculosis or tularemia. It is therefore very important to ask for bacterial culture. It is thought that the pathogen is transmitted by ingestion of food contaminated by rodents and birds. Food hygiene (storage and preparation) is the best way to avoid this infection. A dead vaccine has been produced and delivered in Europe but its effectiveness is questionable. There is on-going research on effective vaccines using live bacteria or recombinant bacteria.

Severe gastroenteritis is also observed in cases of leptospirosis and rodents are also the source of contamination of the environment.

Clostridium piliforme (Tyzzer's disease) has also caused fatal necrotizing typhlocolitis in two postnatal cotton-top tamarins (Sasseville et al., 2007).

Viral infections: "Callitrichid hepatitis" or lymphocytic choriomeningitis is a viral disease so far only found in zoos. There are few specific clinical signs and mortality rates are high. Necropsy findings include swollen liver, fluid in body cavity and occasionally haemorrhages and jaundice. It is caused by an arenavirus carried by mice and a classical mode of transmission to callitrichids is by feeding them pinkies. It is not recommended, therefore, to offer these items. They can also be contaminated when hunting and eating wild mice.

Severe gastroenteritis may be due to measles or Hepatitis A viruses.

Parasites: Each time a diarrhoeal episode is investigated, a faecal screening for parasites is necessary. Drawings of the most common parasite ova found in primates can be found in Fowler (1986). Finding a new parasite in a collection must lead to investigation of the parasite life cycle and control of the intermediate hosts when they occur.

In the case of nematodiasis (e.g. infection by *Strongyloïdes* sp), a drug of the benzimidazole family or Ivermectin must be used.

Treatment for *Prostenorchis elegans* is much more difficult. A high dosage of mebendazole (100 mg/kg) may be unsuccessful and surgical removal of the digestive worms may be required. Cockroaches are the intermediate hosts of this parasite.

In the case of *Capillaria hepatica* infection, eggs and adults are found in the biliary ducts of the liver. Unembryonated eggs are shed by rodents and must pass through the intestine of a carnivore before becoming embryonated and being ingested by a new rodent or accidentally by a primate.

Gongylonema pulchrum is a parasite of the mouth, lips and oesophagus.

Trichospirura leptostoma is a parasite of the pancreatic duct and can lead to a wasting disease (see specific chapter below). Flukes parasitizing the biliary tract are also known.

If amoebiasis (e.g. infection by *Entamoeba histolytica*) is recognized, the treatment requires metronidazole (e.g. metronidazole benzoate orally). The same drug can be used for *Giardia* which causes diarrhea and malabsorption.

Cryptospridium is a protozoan that can cause severe enteritis and death. No specific treatment is available and thorough disinfection (using disinfectant for coccidiosis) of the enclosures should follow this diagnosis.

Fungi: Moniliasis is caused by *Candida* sp. This fungus normally occurs in the digestive tract and infection classically occurs in the mouth and the intestines after prolonged antibiotic treatment. If necessary, it may be treated with amphotericin B or miconazole.

Inflammatory diseases: Non infectious diarrhoea may be due to diet and/or stress and inflammatory colitis resembling Crohn's disease in man can be seen. It generally severely affects the general condition of callitrichids (see specific chapter below).

Hepatosiderosis: Hepatic haemosiderosis is an important cause of debility and premature death in captive marmosets. Studies indicate that dietary iron intake can directly influence hepatic iron concentration in these primates. The dietary iron content should be investigated if such a liver lesion is recognized. The National Research Council's recommended value is 180mg/kg of diet. One must also consider that vitamin C enhances gut absorption of iron.

Hyperbilirubinemia is found in golden lion tamarin females where this benign pathology causes jaundice. Affected specimens are removed from the breeding programme because the etiology is not understood.

Gall bladder stones: These cystine stones have been found in several species, mostly as incidental radiographic or post-mortem findings, but they can cause cholelithiasis and even lead to perforation of the gall bladder and, then, peritonitis. There is no known specific cause.

Gastric bloat: This acute condition occurs for unknown reasons and may be associated with other conditions such as diarrhoeal episodes. It requires immediate relief via intubation of the stomach.

Neoplasms: Colonic adenocarcinomas associated with chronic colitis are classically described in cotton-top tamarins (*Saguinus oedipus*).

Rectal prolapse: Rectal prolapse may be associated with chronic diarrhoea. Many cases involve intussusception and surgical treatment should be considered. Action must be done quickly as

the individual itself or the other members of the family will explore and damage this strange red thing. The gut can be sutured to the abdominal wall in order to prevent recurrence but the main cause of the prolapse must be searched for and treated.

Teeth: Tooth decay is common and is mostly due to inadequate diets, accidents and age. It is essential that potential sources of infection be treated and the teeth should be examined each time a monkey is handled, whether or not a tooth problem is suspected (loss of appetite, salivation or difficulty when chewing). Root infections of the upper canine often produce a swollen lesion below the eye and recurrent abscesses require extraction of the tooth.

2.7.12.2   Respiratory system

Bacterial infections: Symptoms include coughing, sneezing, nasal discharge and breathing difficulties. The following pathogens are often found at bacteriological examination: *Streptococcus*, *Klebsiella*, *Haemophilus*, *Bordetell*a, *Pasteurella*, and *Staphylococcus*. Overheated environments and low humidity may favour these infections and their spread. Maintaining the inside temperature at 18 to 20°C and giving access to outdoor enclosures as often as possible seems to be a good solution.

These diseases require antibiotic treatment and supportive therapy when the general condition of the animal is affected.

Tuberculosis is not frequent in callitrichids but this possibility must not be forgotten.

Viral infections: Several viruses (measles, influenza, parainfluenza, Sendai, herpesvirus etc) may cause fatal diseases. Sources of contamination are usually humans (and mice for Sendai) and, consequently, anybody suffering from a respiratory infection should be kept out of the premises.

Parasitic infections: Toxoplasmosis is contracted by ingesting food contaminated with cat feces or eating small preys such as rodents and birds. Signs of acute pneumonia are noticed but digestive and nervous system signs may also be recorded. This infection is often fatal, especially for infants. The tachyzoïtes are recognized on microscopic examination of the lung (Juan-Sallés et al., 1998). Treatment is theoretically possible with sulfonamide and pyrimethamine, but it is much wiser to control vermin and feral cats.

Strongyliasis may be revealed by coughing and dyspnea. Fecal examination is necessary for etiological diagnosis, and treatment requires classic anthelmintic drugs.

Fungal infections: *Cryptococcus neoformans* may cause a respiratory disease and must be treated with amphotericin B. Infection by *Aspergillus* does not seem to occur frequently in non-human primates.

Diaphragmatic hernia: A high incidence of retrosternal diaphragmatic hernia is known to occur in the captive population of golden lion tamarins (*Leontopithecus rosalia*). Due to the location and degree of the defect, clinical signs are related to the protrusion of abdominal organs into the thorax cavity. This condition may be detected by X-ray. It is unknown whether the hernia is genetically transmitted and it is essential that this lesion be searched for whenever opportunities occur (laparotomy, X-ray examination, necropsy) and the information sent to the breeding programme coordinator. The condition has also been found in a few golden-headed lion tamarins. Diagrams to help with the recognition of diaphragmatic hernia on autopsy and the coding of its severity can be found in the golden lion tamarin husbandry manual (Golden Lion Tamarin Management Committee, 1996).

2.7.12.3   Urinary system

Glomerulonephropathies are quite common in callitrichids. Immune-mediated mechanisms may lead to deposition of immunoglobulin in glomeruli and then to glomerulonephritis. Glomerulonephritis is a frequent finding at post-mortem examination in *Goeldi's monkeys*.

Pyelonephritis and bacterial cystitis may occur.

Leptospirosis causes nephritis, haemolysis, haemoglobinuria and icterus. Primates can get contaminated when eating rodents or in case their food is contaminated by rodent urine.

Renal disease in pygmy marmosets looks like hypertensive nephropathy associated with vascular lesions.

2.7.12.4   Reproductive system

Pregnancy diagnosis is possible by means of visual examination, abdominal palpation, radiography, echography, and blood and urine analyses.

Abortions and stillbirths: Females often produce two young twice a year, and abortions and stillbirths are not rare. Many infectious diseases (toxoplasmosis, leptospirosis and listeriosis, for instance) may specifically lead to these pathologies and laboratory examination of the foetuses is very important for understanding the problem. It is at a minimum absolutely necessary to differentiate stillborn babies from live born infants that have died shortly after birth because of maternal neglect. Abortions may also be caused by stress.

Dystocia: Monitoring pregnant females by daily observation of appetite, increase in abdominal girth, locomotion, and alertness will enable early intervention if a delivery problem occurs. As soon as the problem is diagnosed, **one must not hesitate to perform a caesarean section** (general anaesthesia, linear laparotomy) because the other options (use of oxytocin, forceps) often lead to complications. The female generally recovers very quickly and may be able to reproduce again a few months later.

Placenta praevia is a condition where the placenta is not at the right place. Uterine haemorrhages can occur before delivery because the placenta covers the opening of the cervix and dystocia resulting in the mother's death is possible.

Bacterial infection: As stated above, this may lead to abortions and infertility. Acute post-partum infections can be fatal.

Hormonal implants: Melengestrol acetate implants may predispose to endometrial hyperplasia and, then, to endometritis or pyometra. Implanted females should, therefore, be monitored for evidence of uterine lesions.

Neoplasms: There are on-going studies to evaluate the potential carcinogenic effects of melengestrol acetate implants (mammary adenocarcinoma and uterine carcinoma). Such neoplasms should be reported to the breeding programme coordinator.

Prostates are often increased in size in aging males.

2.7.12.5   Locomotor system

Nutritional diseases: Metabolic bone diseases (rickets in growing animals and osteomalacia in adults) may develop if the diet is not properly balanced for proteins, calcium, phosphorus and

vitamin D3, and if callitrichids are not exposed to sufficient sun light or artificial ultraviolet light (see specific section for further information on diet). These metabolic diseases may also accompany primary diseases of the kidneys, liver and intestines as the integrity of these organs is necessary for the proper absorption and use of the different elements of the diet. Clinical signs are lethargy, inappetence, weight loss, skeletal deformities, fractures and paralysis of the hind legs. Normal circulating levels of 1 alpha, 25-dihydroxyvitamin D3 are 4 to 10 times higher than in other primates.

Congenital defects such as lack of bones, deformed fingers etc. have been seen, sometimes associated with treatment of the mother during pregnancy.

Fractures of the long bones and dislocations are not rare after traumas. Diagnosis may be quite easy with or without X-rays. Dislocations can be easily replaced on an anaesthetized specimen but fractures may be difficult to manage due to the small size of the bones. Such specimens can be isolated for a while and this "cage therapy" usually gives good results.

Necrosis of extremities (tail, toes, fingers) is common after severe traumas (bites, frost bite) or in cases of Wasting Sisease.

Wasting syndrome: Muscular atrophy, weakness and even paralysis of the hind limbs are classically reported in marmosets suffering from this syndrome. See under "General body condition".

2.7.12.6   Nervous system

Etiological diagnosis requires CSF examination and is often possible only at necropsy.

Bacterial infection: Several bacteria may cause meningitis and encephalitis with the following possible symptoms: anorexia, lethargy, ataxia, paresis, paralysis, abnormal postures and involuntary eye movements. *Diplococcus pneumoniae* and *Haemophilus influenzae* are commonly found in healthy humans and are possible causes for such infections in primates following respiratory contamination. Antibacterial drugs able to penetrate the blood brain barrier are necessary for treatment (amoxicillin, ampicillin, sulfonamides).

Parasitic infection: Toxoplasmosis may cause ataxia, paresis and convulsions (see under "Respiratory system: Parasitic infection").

Encephalitozoonosis: Encephalitozoon cuniculi may be an emerging disease in callitrichids colonies. Infections have occurred at least in tamarins and lion tamarins. The infection seems to be transferred vertically and causes high mortality in neonatal and juvenile specimens. The main pathologic findings were vasculitis, myocarditis, hepatitis, interstitial pneumonia, skeletal myositis, meningoencephalitis, adrenalitis, tubulointerstitial nephritis, myelitis, sympathetic ganglioneuritis, and retinitis. Central nervous system lesions were the most prominent findings in cotton-top tamarins (Reetz et al., 2004, Juan-Sallés et al., 2006).

The raccoon parasite, *Baylisascaris*, may cause cerebrospinal nematodiasis (larva migrans).

Fungal infection: *Cryptococcus neoformans* causes ataxia and epilepsy. It must be treated with amphotericin B.

Viral infection: Contact with humans with open herpes oral lesions, or with squirrel monkeys and other cebids, which can carry other herpes viruses, can lead to fatal cases in callitrichids. Vesicles and ulcers are noticed on the skin and mucous membranes. A severe encephalitis may kill the monkey within 2 days.

Encephalitis is also a possible symptom of measles.

Callitrichids are susceptible to Equine Encephalitis Viruses and it is suspected that they are also susceptible to West Nile Encephalitis Virus.

Epilepsy: Epileptic seizures may be due to diseases of the central nervous system or to head traumas and hypoglycaemia. Lead toxicity (primates eating or chewing some paints) may also cause this symptom.

Epilepsy has been reported in lion tamarins (*Leontopithecus* spp.) and investigations are ongoing to determine the cause of this occurrence. Any cases of unknown origin should be reported to the breeding program coordinator.

Botulism may kill callitrichids after paralysis of the larynx and respiratory muscles. They become intoxicated after ingestion of badly preserved animal products and the first sign is that they are unable to swallow. Diagnosis is difficult, and requires detection of the toxin in the digestive tract of the dead specimen thanks to mice inoculation.

Traumas: new-born fallen from parents or helpers on hard soil may present severe central nervous system haematomas which can be fatal.

2.7.12.7   Skin and mucous membranes

Color anomalies are sometimes noticed in newborns (e.g. harlequin *Callimico goeldi*). Vitiligo is an acquired lack of pigmentation and affected specimens may present white spots. Etiology is not completely understood.

Ectoparasites: Mites (*Sarcoptes* or sarcoptiform species, *Demodex*) have been recorded in callitrichids. Associated clinical signs include pruritus, alopecia, thickening and scaling of the skin and even loss of appetite and weight loss. Diagnosis is based on identification of the parasite in skin scrapings through a microscope and treatment requires classical external drugs such as pyrethroids, amitraz etc.

Ticks are not common and not dangerous by themselves but they can be a vector for blood parasites such as *Babesia* (see babesiosis under 2.7.12.8 "Cardiovascular system"). Fleas have also been recorded in animals in very poor condition.

Bites by cage mates may lead to abcesses which require debridement. Another complication of these small traumas on the extremities is necrosis.

Zinc deficiency has been associated with alopecia and thickening of the skin of the tail, perineum, limbs and trunk. This condition improves after providing zinc in drinking water.

WMS: alopecia of the tail and necrosis of the extremities (tail and finger tips) are seen under this condition.

Viral infection: see "viral infections of the nervous system".

2.7.12.8   Cardiovascular system

Bacterial endocarditis can follow local infections and chronic bacteraemia. It is therefore very important to treat efficiently infections such as tooth abscesses.

Viral infection: EMCV may be a threat to callitrichids. It is transmitted by feed contaminated by rodent faeces and urine.

Parasitic infection: Microfilariae of the genus *Dipetalonema* can be seen in the blood of callitrichids while adults are found in pleural and peritoneal spaces where they may cause inflammation.

Babesiosis is caused by a blood parasite transmitted by ticks. The sick individual exhibits anemia and icterus and may quickly die unless specific and supportive treatment is given.

Cardiac insufficiency: Cardiomyopathies due to vitamine E and/or Selenium deficiency, infections, anaemia, etc. are possible. Pygmy marmosets that are offered high cholesterol diets may have arteriosclerosis and exhibit symptoms associated with hypertension.

Vitamin E deficiency may be involved in the development of haemolytic anaemia, myopathy, and steatitis in callitrichids.

Anticoagulant drugs intoxication: Rodent control procedures are much needed but they always use anticoagulant drugs, which can be fatal to callitrichids if they chase and eat "treated" rodents. Massive haemorrhages in various organs occur and can be fatal. Treatment involves vitamin K.

2.7.12.9 General body condition

Wasting syndrome: chronic loss of weight and muscle wasting of unknown aetiology has often been reported in marmosets and is referred to under the collective name "Wasting Marmoset Syndrome" or WMS.

The affected specimens show loss of weight, ungroomed or "spiky" coat, lethargy, muscular atrophy and weakness. Diarrhea is not a constant accompanying sign but is often seen (chronic enteritis and colitis). Some of the most common blood abnormalities are severe anemia, hypocalcaemia and low total protein. Examination of the muscle sometimes shows morphological changes similar to those in vitamin E deficiency and examination of the bones may reveal signs of metabolic bone disease.

Although a change in the intestinal bacterial flora and the presence of parasites in the pancreas have been suggested as possible etiologies, one must also consider that it has been associated with low dietary protein concentration and low serum vitamin E levels. More recent research studies suggest that lesions are similar to lesions found in human beings affected by Celiac Sprue which cause is hyper sensitivity to some cereal proteins.

Treatment of any kind is rarely successful in the long term. The following can be tried: broad spectrum antibiotics, vitamin E and Selenium, iron, Calcium and vitamin D3, high protein diet, kaolin, electrolytes. The addition of gum arabic (Acacia gum) to the diet of Geoffroy's marmoset (*Callithrix geoffroyi)* has been found to be helpful in treating chronic diarrhea, and reversing weight loss associated with it (Carroll 1997, Herron et al. 2001). The removal of wheat derived items from the diet and use of sulfasalazine should be tried in case of colitis similar to human Celiac Sprue.

Septicemia: This is quite frequent and may be encountered after a digestive infection, a bite or other trauma. The following pathogens have commonly been isolated from the blood: *Aeromonas hydrophila*, *Campylobacter* spp, *Corynebacterium pseudotuberculosis*, *Escherichia coli*, *Haemophilus* spp, *Klebsiella pneumoniae*, *Pasteurella multocida*, *Pseudomonas aeruginosa*, *Salmonella* spp., *Shigella* spp., *Staphylococcus* spp., *Streptococcus* spp., *Yersinia* spp.

Toxoplasma gondii infection is discussed under "Parasitic infections of the respiratory system" but the course of an acute infection is often septicaemic with general symptoms leading to death in a few days.

Neoplasms: Some herpes viruses (*Herpesvirus ateles, Herpesvirus saimiri*, Human EBV) can experimentally cause lymphoproliferative disease in callitrichids.

Hypothermia: Abandoned newborn callitrichids often exhibit hypothermia if they are not quickly found. Sick animals, young or adult, may also be hypothermic and it is always important to provide warmth to them. It can be done by the mean of heating lamps or pads, hair drier and even warm enema or stomach tubing with warm liquid in emergency conditions.

Hypothermia during anaesthetic procedures is common and should be prevented.

Hypoglycaemia: A high incidence of this condition is seen in callitrichids, probably due to their high metabolic rates and frequency of feeding. Animals are found on the soil and weak. It can be fatal but it is usually reversible with an IP infusion of glucose or with tube feeding sugar or fruits.

2.7.12.10   Metabolic diseases

Amyloidosis is a fairly frequent condition where modified proteins are deposited in several organs. This is secondary to chronic inflammation such as enteritis. These proteins cannot be eliminated and symptoms vary widely depending upon the site of amyloid deposition.

Haemosiderosis and haemochromatosis: hepatosiderosis has been discussed under digestive disorders but the liver and other organs may be affected in the case of haemosiderosis and haemochromatosis.

Diabetes: Obesity and gestation may also be associated with diabetes.

Lipidosis: This abnormal hepatorenal lipid deposition due to disturbance in lipid metabolism associated with obesity and diabetes has been described.

2.7.13   Appendix

Physical restraint: The animal can be held with leather gloves or just disposable gloves if the animal is weak or sedated. Attention must be paid to its teeth. Even weak animals can administer a deep bite, which carries a risk of infection. This is a particularly important consideration with sick animals that may be suffering from infectious diseases. One hand stabilizes the upper body with the thumb and the forefinger around the neck; the other hand holds the hind legs. See also Section 2.6.

Microchip identification: The microchip is inserted subcutaneously between the shoulders. It has been reported that the device may migrate and may even be lost via the insertion site. In order to avoid this problem, it may be necessary to insert the chip towards the tail, i.e. caudally to the insertion site, to reduce the likelihood of migration back through the insertion site. The site may also be sealed with a drop of surgical glue.

Blood sampling: The animal may be anaesthetized or not. It is held on the back, the thighs being opened. The femoral artery and the more superficial femoral vein can be located by the arterial pulse. A 0.6 to 0.8 mm diameter needle is inserted into the vein and 1 ml or more of blood may be drawn. The jugular vein can also be punctured on an anaesthetized animal.

Table 2.7.13-1 gives haematological values for 2 *Callithrix*, 1 *Mico*, 1 *Cebuella*, 8 *Saguinus*, 1 *Leontopithecus* and 1 *Callimico* species while Table 2.7.13-2 gives a range of biochemical parameters for the same species (data generated by ISIS).

Intraperitoneal injection: The animal (anaesthetized or not) is held on its back. The abdominal muscle is elevated by pinching it between the thumb and the forefinger at the midline. Once the needle has penetrated the abdominal wall, it can be readily palpated within the abdomen to ensure that the injection is not within a loop of bowel or is subperitoneal.

Tuberculosis testing: There is no universally accepted method for tuberculosis testing of primates. The method generally recommended is the intradermal injection of 0.1 ml of tuberculin at the edge of the eyelid or on the abdominal skin. This site is much recommended for small species like the Callitrichidae. Bovine and avian PPD are usually used and swelling and/or erythema occurring within 72 hours is considered a positive result. Other tests may be tried in suspect cases (serology [ELISA], X-rays, bacterial culture), but they are not routinely used.

Injection anaesthesia: The following dosages may be used in order to obtain general anaesthesia in the callitrichids by means of IM injection:
- 10–20 mg/kg ketamine
- 2 mg/kg ketamine + 2.5 mg/kg xylazine
- 5 mg/kg ketamine + 100 µg/kg medetomidine
- 8–10 mg/kg zolazepam + 8–10 mg/kg tiletamine

TABLE 2.7.13-1. HAEMATOLOGY—CALLITRICHIDAE (MEAN ± SD (N))

	Callithrix jacchus	*Cebuella pygmaea*	*Mico argentata*	*Callithrix geoffroyi*
	Common	**Pygmy**	**Silvery**	**White-fronted**
WBC 10^3/UL	6.1 ± 2.2 (30)	9.6 ± 8.5 (48)	8.2 ± 2.3 (4)	8.08 ± 3.6 (8)
RBC 10^6/UL	5.6 ± 0.78 (25)	6.5 ± 1.2 (42)	6.1 ± 1.1 (2)	6.7 ± 0.89 (5)
HGB gm/dl	15.0 ± 1.4 (40)	13.6 ± 1.6 (19)	15.5 ± 1.2 (8)	16.7 ± 1.0 (4)
HCT %	44.6 ± 7.1 (45)	42.5 ± 4.9 (46)	46.4 ± 7.1 (11)	50.8 ± 3.8 (8)
MCH mg/dl	25.8 ± 2.7 (24)	66.8 ± 12.2 (42)	24.8 ± 0.4 (2)	23.6 ± 2.6 (3)
MCHC uug	34.2 ± 4.5 (39)	32.3 ± 2.2 (19)	34.1 ± 1.8 (8)	33.2 ± 3.6 (4)
MCV fl	74.3 ± 10.9 (24)	66.8 ± 12.2 (42)	74.3 ± 1.1 (2)	74.2 ± 8.5 (5)
SEGS 10^3/UL	3.2 ± 1.5 (24)	4.6 ± 3.7 (46)	3.3 ± 1.3 (3)	5.1 ± 2.1 (6)
BANDS 10^3/UL	0.17 ± 0.08 (5)	0.26 ± 0.41 (7)	–	–
LYMPHS 10^3/UL	3.0 ± 1.6 (24)	4.6 ± 4.7 (46)	4.3 ± 1.03 (3)	3.5 ± 4.1 (6)
MONOS 10^3/UL	0.25 ± 0.18 (15)	0.32 ± 0.47 (40)	0.47 ± 0.63 (3)	0.24 ± 0.12 (6)
EOS 10^3/UL	0.23 ± 0.14 (15)	0.15 ± 0.19 (27)	0.20 ± 0.13 (2)	0.075 ± 0.015 (2)
BASOS 10^3/UL	0.16 ± 0.15 (7)	0.15 ± 0.13 (25)	–	0.085 ± 0.0 (1)
NRBC /100wbc	3.0 ± 2.0 (13)	2.0 ± 1.0 (22)	2.0 ± 0 (1)	18.0 ± 28.0 (3)
Platelet cnt 10^3/UL	609 ± 200 (6)	–	–	–

	Saguinus oedipus	*Saguinus imperator*	*Saguinus mystax*	*Saguinus fuscicollis*
	Cotton-top Tamarin	**Emperor Tamarin**	**Moustached Tamarin**	**Saddle-back Tamarin**
WBC 10^3/UL	11.2 ± 5.2 (95)	9.5 ± 3.7 (54)	12.3 ± 2.8 (23)	8.7 ± 4.06 (12)
RBC 10^6/UL	6.3 ± 0.61 (76)	6.4 ± 0.90 (52)	6.06 ± 0.65 (10)	5.39 ± 1.02 (15)
HGB gm/dl	15.9 ± 1.7 (82)	14.1 ± 1.6 (47)	14.3 ± 1.9 (27)	14.0 ± 2.5 (20)
HCT %	47.9 ± 5.0 (99)	45.5 ± 5.6 (53)	48.2 ± 6.5 (36)	44.4 ± 6.6 (22)
MCH mg/dl	25.4 ± 1.5 (71)	22.6 ± 2.4 (46)	24.2 ± 0.7 (5)	26.4 ± 3.3 (15)
MCHC uug	33.1 ± 2.3 (81)	31.3 ± 1.9 (47)	30.1 ± 2.6 (27)	33.1 ± 3.9 (19)
MCV fl	76.3 ± 5.4 (74)	71.6 ± 8.0 (52)	78.2 ± 5.7 (10)	78.9 ± 7.6 (14)
SEGS 10^3/UL	7.03 ± 4.5 (90)	5.2 ± 2.4 (54)	5.1 ± 1.8 (17)	8.2 ± 4.5 (5)
BANDS 10^3/UL	0.33 ± 0.50 (20)	0.27 ± 0.34 (5)	0.08 ± 0.01 (2)	–
LYMPHS 10^3/UL	3.3 ± 1.7 (90)	3.6 ± 2.4 (54)	6.4 ± 2.5 (17)	1.9 ± 0.92 (5)
MONOS 10^3/UL	0.54 ± 0.44 (80)	0.51 ± 0.41 (49)	0.85 ± 0.52 (16)	0.30 ± 0.12 (3)
EOS 10^3/UL	0.21 ± 0.17 (47)	0.23 ± 0.16 (24)	0.39 ± 0.26 (12)	0.28 ± 0.17 (3)
BASOS 10^3/UL	0.10 ± 0.06 (24)	0.16 ± 0.10 (24)	0.22 ± 0.20 (5)	0.18 ± 0.08 (2)
NRBC /100wbc	1.0 ± 1.0 (22)	2.0 ± 4.0 (8)	3.0 ± 2.0 (15)	9.0 ± 19 (9)
Platelet cnt 10^3/UL	361 ± 74 (14)	626 ± 224 (5)	840 ± 142 (5)	546 ± 113 (3)
RETICS %	–	1 7.7± 0.0 (1)	–	–

	Saguinus geoffroyi Geoffroy's Tamarin	*Saguinus labiatus* Red-bellied Tamarin	*Saguinus midas* Red-handed Tamarin	*Saguinus nigricollis* Black-and-white Tamarin
WBC 10^3/UL	13.5 ± 5.9 (14)	13.4 ± 4.4 (3)	15.6 ± 6.7 (48)	17.2 (1)
RBC 10^6/UL	6.2 ± 0.73 (11)	5.8 ± 1.8 (3)	6.3 ± 0.56 (15)	6.0 (1)
HGB gm/dl	15.0 ± 1.2 (19)	14.1 ± 4.0 (3)	16. 1 ± 1.9 (47)	14.1 (1)
HCT %	46.3 ± 3.8 (20)	39.3 ± 11.7 (3)	49.5 ± 5.5 (61)	42.0 (1)
MCH mg/dl	24.6 ± 1.3 (9)	24.4 ± 1.5 (3)	26.5 ± 1.2 (15)	23.5 (1)
MCHC uug	32.0 ± 1.5 (18)	36.1 ± 0.80 (3)	32.9 ± 2.5 (46)	33.6 (1)
MCV fl	71.3 ± 9.8 (11)	67.5 ± 3.6 (3)	80.1 ± 3.6 (15)	70.0 (1)
SEGS 10^3/UL	8.5 ± 5.1 (14)	7.2 ± 3.2 (3)	8.7 ± 4.7 (37)	11.7 (1)
BANDS 10^3/UL	0.11 ± 0.0 (1)	0.21 ± 0.23 (3)	1.05 ± 1.8 (11)	–
LYMPHS 10^3/UL	4.1 ± 1.3 (14)	5.2 ± 1.9 (3)	5.2 ± 3.2 (39)	4.3 (1)
MONOS 10^3/UL	0.73 ± 0.82 (14)	0.72 ± 0.21 (3)	1.1 ± 0.82 (35)	0.86 (1)
EOS 10^3/UL	0.12 ± 0.10 (4)	0.0 ± 0.0 (1)	0.63 ± 0.67 (27)	0.344 (1)
BASOS 10^3/UL	0. 11 ± 0.09 (5)	0.08 ± 0.0 (1)	0.18 ± 0.11 (12)	–
NRBC /100wbc	1.0 ± 1.0 (5)	–	7.0 ± 10.0 (15)	–
Platelet cnt 10^3/UL	386 ± 0 (1)	–	397 ± 132 (5)	–
RETICS %	–	–	6.4 ± 3.5 (3)	–

	Leontopithecus rosalia Golden Tamarin	*Callimico goeldi* Goeldi's Monkey
WBC 10^3/UL	8.1 ± 3.7 (378)	6.2 ± 2.8 (262)
RBC 10^6/UL	6.2 ± 0.85 (305)	6.6 ± 0.71 (250)
HGB gm/dl	15.3 ± 1.9 (343)	14.3 ± 1.7 (261)
HCT %	45.6 ± 5.1 (375)	44.1 ± 5.0 (270)
MCH mg/dl	24.8 ± 2.8 (296)	21.5 ± 1.8 (250)
MCHC uug	33.7 ± 2.4 (323)	32.5 ± 2.3 (261)
MCV fl	74.0 ± 9.1 (302)	66.0 ± 5.2 (250)
SEGS 10^3/UL	5.3 ± 3.1 (338)	3.3 ± 2.09 (257)
BANDS 10^3/UL	0.14 ± 0.17 (99)	0.12 ± 0.11 (41)
LYMPHS 10^3/UL	2.4 ± 1.5 (339)	2.5 ± 1.5 (257)
MONOS 10^3/UL	0.30 ± 0.27 (272)	0.18 ± 0.15 (223)
EOS 10^3/UL	0.29 ± 0.30 (231)	0.16 ± 0.17 (154)
BASOS 10^3/UL	0.16 ± 0.16 (80)	0.04 ± 0.04 (15)
NRBC /100wbc	2.0 ± 2.0 (51)	2.0 ± 3.0 (40)
Platelet cnt 10^3/UL	502 ± 165 (113)	8 72 ± 233 (108)
RETICS %	–	0.0 ± 0.0 (5)

TABLE 2.7.13-2: CLINICAL CHEMISTRIES—CALLITRICHIDAE

	Callithrix jacchus	*Cebuella pygmaea*	*Mico argentata*	*Callithrix geoffroyi*
	Common Marmoset	**Pygmy Marmoset**	**Silvery Marmoset**	**White-fronted Marmoset**
Glucose mg/dl	177 ± 65 (16)	161 ± 78 (43)	220 ± 85 (3)	243 ± 179 (4)
BUN mg/dl	19 ± 5 (15)	18 ± 8 (42)	11 ± 6 (3)	16 ± 1 (4)
Creatinine mg/dl	0.7 ± 0.2 (10)	0.5 ± 0.2 (28)	–	0.6 ± 0.2 (4)
Uric acid mg/dl	0.5 ± 0.2 (10)	3.6 ± 6.8 (11)	–	0.3 ± 0.4 (2)
Calcium mg/dl	9.5 ± 1.1 (17)	10.0 ± 2.0 (35)	9.0 ± 0.9 (6)	10.2 ± 0.4 (5)
Phosphorus mg/dl	5.3 ± 1.9 (15)	7.2 ± 4.3 (18)	7.2 ± 2.2 (6)	5.0 ± 0.5 (4)
Sodium mEq/L	147 ± 8 (12)	156 ± 6 (13)	153 ± 1 (2)	164 ± 0 (2)
Potassium mEq/L	4.9 ± 2.6 (12)	3.8 ± 1.5 (13)	3.4 ± 0.3 (2)	2.9 ± 1.7 (2)
Chloride mEq/L	103 ± 11 (10)	116 ± 8 (2)	96 ± 6 (2)	115 ± 1 (2)
Iron mcg/dl	129 ± 0 (1)	–	–	55± 51 (2)
Bicarbonate mMol/L	–	5.8 ± 1.0 (4)	–	–
Cholesterol mg/dl	176 ± 73 (7)	216 ± 95 (23)	88 ± 28 (2)	106 ± 81 (4)
Triglycerides mg/dl	160 ± 43 (2)	129 ± 43 (10)	–	290 ± 260 (2)
Total proteins gm/dl	6.8 ± 1.0 (17)	6.1 ± 0.9 (33)	7.5 ± 0.6 (3)	7.7 ± 0.7 (4)
Albumin gm/dl	5.1 ± 0.6 (4)	4.2 ± 0.8 (13)	–	–
Globulin gm/dl	1.7 ± 0.5 (4)	2.1 ± 0.7 (13)	–	–
AST (SGOT) IU/L	112 ± 112 (11)	64 ± 51 (35)	7 ± 1 (2)	109 ± 32 (3)
ALT (SGPT) IU/L	13 ± 24 (14)	15 ± 23 (30)	0 ± 0 (2)	14 ± 10 (4)
Tot. Bilirubin mg/dl	0.2 ± 0.3 (8)	0.3 ± 0.3 (13)	–	0.1 ± 0.1 (2)
Dir. Bilirubin mg/dl	0.0 ± 0.0 (1)	0.0 ± 0.0 (5)	–	–
Indir. Bilirubin mg/dl	0.1 ± 0.0 (1)	0.3 ± 0.3 (5)	–	–
Alk Phosp. IU/L	125 ± 64 (13)	322 ± 260 (31)	211 ± 29 (2)	97 ± 19 (4)
LDH IU/L	551 ± 429 (7)	354 ± 270 (13)	312 ± 8 (2)	414 ± 302 (3)
CPK IU/L	543 ± 0 (1)	768 ± 1055 (14)	–	180 ± 50 (2)
CO2 mMol/L	–	14.8 ± 8.3 (4)	–	–
GGT IU/L	–	5 ± 3 (7)	–	–
Lipase U/L	–	192 ± 188 (2)	–	–

	Saguinus oedipus	*Saguinus imperator*	*Saguinus mystax*	*Saguinus fuscicollis*
	Cotton-top Tamarin	**Emperor Tamarin**	**Moustached Tamarin**	**Saddle-back Tamarin**
Glucose mg/dl	179 ± 82 (62)	151 ± 58 (50)	117 ± 63 (18)	173 ± 66 (6)
BUN mg/dl	15 ± 8 (69)	14 ± 4 (49)	13 ± 5 (19)	14 ± 5 (4)
Creatinine mg/dl	0.7 ± 0.3 (60)	0.6 ± 0.2 (50)	0.7 ± 0.4 (3)	0.5 ± 0.2 (4)
Uric acid mg/dl	1.0 ± 0.7 (25)	0.2 ± 0.2 (17)	–	0.8 ± 0.1 (2)
Calcium mg/dl	8.9 ± 0.9 (67)	9.2 ± 0.8 (49)	8.7 ± 1.2 (24)	8.9 ± 0.9 (8)
Phosphorus mg/dl	4.8 ± 1.5 (61)	5.5 ± 1.8 (47)	8.0 ± 3.0 (20)	5.2 ± 1.1 (7)
Sodium mEq/L	150 ± 8 (52)	156 ± 8 (40)	154 ± 7 (13)	154 ± 1 (4)
Potassium mEq/L	4.0 ± 0.8 (55)	3.9 ± 0.9 (40)	4.9 ± 1.6 (13)	3.4 ± 0.7 (4)
Chloride mEq/L	104 ± 8 (51)	112 ± 5 (41)	104 ± 8 (13)	110 ± 1 (4)
Iron mcg/dl	127 ± 73 (5)	–	–	–
Magnesium mg/dl	2.4 ± 0 (1)	–	–	–
Bicarbonate mMol/L	20.5 ± 7.0 (4)	16.8 ± 5.4 (15)	–	–
Cholesterol mg/dl	121 ± 42 (60)	106 ± 45 (50)	106 ± 79 (13)	65 ± 12 (3)
Triglycerides mg/dl	69 ± 32 (30)	103 ± 71 (25)	–	80 ± 0 (1)
Total proteins gm/dl	6.6 ± 0.7 (64)	6.3 ± 0.7 (50)	6.5 ± 0.7 (15)	7.5 ± 1.0 (50
Albumin gm/dl	3.8 ± 0.5 (49)	3.5 ± 0.5 (43)	3.5 ± 1.0 (2)	4.2 ± 0.2 (2)
Globulin gm/dl	2.8 ± 0.5 (49)	2.8 ± 0.5 (43)	2.3 ± 1.3 (2)	2.5 ± 0.1 (2)
AST (SGOT) IU/L	157 ± 56 (57)	156 ± 69 (48)	56 ± 85 (14)	491 ± 892 (5)
ALT (SGPT) IU/L	38 ± 41 (63)	18 ± 15 (45)	7 ± 14 (15)	26 ± 32 (4)
Tot. Bilirubin mg/dl	0.2 ± 0.2 (58)	0.4 ± 0.3 (46)	0.1 ± 0.1 (6)	0.3 ± 0.4 (2)
Dir. Bilirubin mg/dl	0.0 ± 0.1 (13)	0.2 ± 0.2 (2)	–	–
Indir. Bilirubin mg/dl	0.2 ± 0.1 (12)	0.2 ± 0.1 (2)	–	–
Amylase SU	575 ± 400 (23)	1202 ± 354 (29)	496 ± 0 (1)	–
Alk Phosp. IU/L	184 ± 110 (57)	179 ± 119 (48)	358 ± 341 (14)	129 ± 68 (4)
LDH IU/L	460 ± 319 (32)	290 ± 92 (19)	594 ± 326 (13)	390 ± 226 (3)
CPK IU/L	645 ± 706 (26)	766 ± 574 (18)	–	–
CO2 mMol/L	18.1 ± 8.3 (26)	17.8 ± 3.9 (6)	24 ± 0 (1)	11.7 ± 3.5 (2)
GGT IU/L	21 ± 21 (26)	8 ± 5 (27)	–	–
Lipase U/L	40 ± 16 (9)	342 ± 609 (5)	–	–
Cortisol ug/dl	570 ± 0 (2)	–	–	–

	Saguinus geoffroyi	*Saguinus labiatus*	*Saguinus midas*
	Geoffroy's Tamarin	Red-bellied Tamarin	Red-handed Tamarin
Glucose mg/dl	199 ± 65 (9)	281 ± 47 (2)	186 ± 69 (29)
BUN mg/dl	15 ± 6 (9)	14 ± 2 (2)	15 ± 6 (25)
Creatinine mg/dl	0.7 ± 0.1 (8)	0.5 ± 0.0 (2)	0.6 ± 0.3 (18)
Uric acid mg/dl	0.3 ± 0.2 (4)	–	4.9 ± 0.0 (1)
Calcium mg/dl	8.9 ± 1.2 (11)	9.4 ± 0.3 (2)	7.7 ± 0.9 (38)
Phosphorus mg/dl	6.3 ± 3.1 (10)	2.5 ± 1.0 (2)	6.8 ± 2.5 (33)
Sodium mEq/L	149 ± 7 (6)	–	153 ± 4 (17)
Potassium mEq/L	4.3 ± 0.9 (6)	–	4.2 ± 1.7 (16)
Chloride mEq/L	103 ± 10 (6)	–	109 ± 6 (15)
Iron mcg/dl	136 ± 6 (2)	–	–
Bicarbonate mMol/L	18.5 ± 2.1 (2)	–	–
Cholesterol mg/dl	96 ± 40 (6)	–	136 ± 98 (14)
Triglycerides mg/dl	127 ± 31 (4)	–	73 ± 0 (1)
Total proteins gm/dl	6.4 ± 0.6 (11)	6.0 ± 0.0 (1)	6.3 ± 1.0 (26)
Albumin gm/dl	3.6 ± 0.7 (5)	–	3.8 ± 0.6 (8)
Globulin gm/dl	2.5 ± 0.5 (5)	–	2.4 ± 0.5 (8)
AST (SGOT) IU/L	287 ± 420 (9)	–	113 ± 79 (21)
ALT (SGPT) IU/L	54 ± 80 (9)	13 ± 4 (2)	8 ± 11 (21)
Tot. Bilirubin mg/dl	0.3 ± 0.3 (7)	–	0.7 ± 0.8 (13)
Dir. Bilirubin mg/dl	0.0 ± 0.0 (2)	–	–
Indir. Bilirubin mg/dl	0.2 ± 0.0 (2)	–	–
Amylase SU	649 ± 536 (5)	–	–
Alk Phosp. IU/L	180 ± 109 (9)	–	225 ± 197 (20)
LDH IU/L	316 ± 94 (5)	–	574 ± 427 (12)
CPK IU/L	968 ± 1179 (2)	–	–
CO2 mMol/L	–	–	13.9 ± 5.1 (5)
Fibrinogen gm/dl	–	200 ± 0 (1)	–

	Leontopithecus rosalia	*Callimico goeldii*
	Golden-lion Tamarin	Goeldi's Monkey
Glucose mg/dl	156 ± 85 (309)	124 ± 44 (226)
BUN mg/dl	14 ± 6 (315)	23 ± 8 (216)
Creatinine mg/dl	0.5 ± 0.2 (263)	0.7 ± 0.4 (138)
Uric acid mg/dl	0.6 ± 0.5 (148)	0.6 ± 0.2 (123)
Calcium mg/dl	9.2 ± 0.9 (277)	9.8 ± 0.7 (181)
Phosphorus mg/dl	4.8 ± 2.1 (259)	5.4 ± 2.2 (167)
Sodium mEq/L	149 ± 4 (229)	150 ± 5 (162)
Potassium mEq/L	3.7 ± 0.9 (230)	4.4 ± 0.8 (166)
Chloride mEq/L	106 ± 5 (234)	108 ± 26 (156)
Iron mcg/dl	210 ± 75 (19)	100 ± 27 (6)
Magnesium mg/dl	1.52 ± 0.62 (19)	2.48 ± 0.27 (8)
Bicarbonate mMol/L	20 ± 7.4 (5)	18.3 ± 2.9 (3)
Cholesterol mg/dl	73 ± 30 (207)	108 ± 26 (156)
Triglycerides mg/dl	102 ± 86 (147)	84 ± 27 (6)
Total proteins gm/dl	6.6 ± 0.7 (304)	6.6 ± 0.6 (213)
Albumin gm/dl	3.7 ± 0.5 (199)	4.1 ± 0.6 (129)
Globulin gm/dl	2.9 ± 0.6 (197)	2.6 ± 0.5 (129)
AST (SGOT) IU/L	108 ± 53 (285)	120 ± 38 (224)
ALT (SGPT) IU/L	86 ± 81 (295)	70 ± 54 (226)
Tot. Bilirubin mg/dl	0.7 ± 0.8 (278)	0.4 ± 0.2 (208)
Dir. Bilirubin mg/dl	0.2 ± 0.4 (89)	0.1 ± 0.1 (12)
Indir. Bilirubin mg/dl	0.3 ± 0.3 (87)	0.2 ± 0.1 (12)
Amylase SU	917 ± 1065 (59)	349 ± 103 (6)
Alk Phosp. IU/L	73 ± 52 (259)	157 ± 68 (144)
LDH IU/L	439 ± 298 (179)	300 ± 163 (128)
CPK IU/L	704 ± 766 (169)	793 ± 1147 (111)
CO2 mMol/L	19.5 ± 6.0 (140)	19.8 ± 6.2 (119)
Fibrinogen gm/dl	167 ± 82 (6)	100 ± 0 (1)
GGT IU/L	53 ± 67 (143)	39 ± 35 (115)
Lipase U/L	25 ± 25 (40)	25 ± 13 (6)

2.8   Special issues

2.8.1   Note

In general, all of the problems and issues faced in keeping and breeding Callitrichidae are discussed and addressed in the chapters preceding this section. For the most part, the guidance provided on enclosure design, diet, social group management and veterinary care is sufficient to maintain and breed most individuals of most species in captivity in Europe.

One species that has proved to be rather more challenging to maintain and breed in numbers, and thus merits particular attention in this "Special Issues" Section, is the pied tamarin *Saguinus bicolor*.

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2.8.2   Pied tamarin (Saguinus bicolor)

Photo credit: Gregory Guida

2.8.2.1 Introduction

In general pied tamarins have proved difficult to keep in captivity and are very sensitive and prone to disease, particularly a wasting syndrome similar to wasting marmoset syndrome (WMS).

The sometimes aggressive and confrontational nature of pied tamarins probably causes increased stress levels when the species is not kept in the appropriate enclosures or social environments. In general the enclosure should be as natural and complex as possible, giving the animals the opportunity to both exhibit natural behaviours and feel secure.

2.8.2.2   Wasting syndrome

Pied tamarins in captivity are particularly prone to a wasting disease similar to wasting marmoset syndrome. The causes are still unknown but gradually instances of this condition are beginning to decline; however, if left untreated, it can be fatal. The main strategy for minimizing instances of wasting is the reduction of any environmental or social stressors.

2.8.2.2.1   Behavioural signs of wasting

Increased aggression towards keeping staff at feeding times is one of the early signs of wasting, often accompanied by diarrhoea. This aggression is probably due to the animal being eager for food because of malabsorption of nutrients. Aggression takes the form of chattering and head shaking and can often be accompanied by the tamarin jumping on the keeper or attempting to scratch or bite the keeper's hands as they are putting the food into the enclosure. The animal may also favour protein items in the feed over other favourites such as banana.

Actively heat-seeking and remaining under a heat source for some time is another behavioural sign that a tamarin is feeling unwell, and therefore it is important to have "hot spots" in the enclosure.

2.8.2.2.2   Physical signs of wasting

Chronic diarrhoea is the primary symptom of wasting in pied tamarins, and in severe cases faeces often has the appearance of masticated food. If prolonged, chronic diarrhoea can often lead

to serious weight loss and even loss of fur caused by malnutrition. Scouring on the underside of the tail and around the anus/perineum can often become apparent with long-term diarrhoea. This can lead to severe alopecia on the tail.
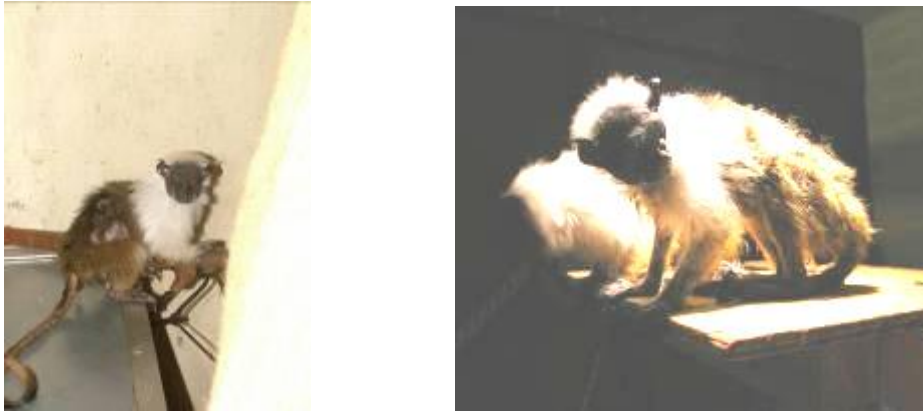
Individuals showing signs of wasting

Pilo-erection of the fur around the neck and head is often a sign that the animal is unwell, and generally poor coat condition is one of the more obvious physical signs of the onset of wasting. In severe cases the tamarin will become lethargic and very weak, appearing noticeably unstable when moving, and in extreme cases falling from cage perching.

2.8.2.2.3   Monitoring

Close, but not stressful, monitoring of these animals is essential as the onset of wasting can be quite gradual, and therefore not picked up in its early stages. It is extremely important that regular individual weights are taken, but this must be done remotely to avoid stress. Several methods can be used to monitor the animals' health, such as weighing and faecal monitoring, without the need for handling which will exacerbate the condition.

Tamarins can be trained to sit on scales for a reward very easily and the frequency with which weights are obtained can be varied depending on the health of the animals. Routine weights should be taken once a month; for animals that are presenting with diarrhoea this should be increased to at least once a week, or daily if possible, in cases of severe wasting. These small bodied primates have fast metabolisms and can lose weight rapidly. Keeping a record of an individual's weight fluctuations may help to pinpoint times of the year or events that precipitate a wasting period.

Simple electronic scales, calibrated to 1 gram, can be moved from unit to unit.

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Weights are obtained by placing the scales on a secure platform in the enclosure (see plate above); treats should be placed on the scales initially to acclimatize the animals to their presence. Weights are then obtained by rewarding the animal for sitting on the scales – treats such as honey work best as they can be smeared on the scales and the animal will remain fairly still whilst the honey is licked off, thus providing a more accurate reading.

Faecal monitoring and grading is a useful tool for diagnosing the severity of the diarrhoea and for monitoring the effect of any treatment on the individual. It has in the past been used as a tool to monitor faecal improvement or decline during dietary changes and during trials of alternative medicine (see faecal grading chart in appendix 1).

2.8.2.2.4   Treatment of wasting syndrome

Individuals suffering from this condition are put on a course of sulfasalazine, a medication used in the treatment of human Crohn's disease. The brand used at Durrell is Salazopyrin Suspension and animals with signs of wasting or individuals that live with the long-term condition are prescribed 0.2 ml of sulfasalazine twice a day, given with the morning and afternoon feeds. It is presented, as with other medication, prior to the main feed to increase the chances of them taking it. Some individuals will take the medication directly from the syringe but other prefer it mixed in a honey solution or with Ensure*, (*see dietary section, DWCT) and then given in a syringe. It can also be presented on banana or in a locust. This treatment can be used effectively long-term for as long as the animal requires treatment. An animal in remission for more than 6 months may be taken off the treatment if no further symptoms occur.

If the condition of animals on the treatment described above continues to decline, then more serious action needs to be taken. Treatment for the symptoms of pied wasting comes in two forms: "soft" treatment and "hard" treatment. At the beginning of treatment a faecal sample is taken and analysed for parasitological and bacteriological infections.

Soft treatment course: Soft treatment is implemented when the individual has lost 25% of its body weight and has persistent diarrhoea. All of the medication is administered orally using favoured food such as banana.
- 10 mg/kg Ciprofloxacin suspension, given orally once a day for 3 weeks.
- 0.25 ml Flagyl (metronidazole 40mg/ml), given orally once a day for 5 days.
- 0.1 ml Cytacon (vitamin B12), given orally for approximately 3 month period (at the present time – to be reviewed).
- ½ tsp Enterodex, added to every feed whilst on antibiotic therapy.
- Dioralyte, added to the water as long as they will drink it (not if it puts them off drinking water).

Hard treatment course: "Hard" treatment is only used in severe cases of wasting where the animal has lost over 33% of its body weight and is weak, lethargic and has lost all interest in food. This consists of a 5-day course of antibiotics and fluids, which have to be administered by injection and therefore require the animal to be caught and handled once a day for the 5-day treatment period. As this treatment is extremely stressful for the animal, and can cause stress to others housed near by, it is only used as a last resort.

The 5-day "hard" treatment is as follows:
- 8 ml Hartmann's fluids given subcutaneously in the interscapular region, once a day for 5 days.
- 0.08 ml (4 mg) Baytril 5% (enrofloxacin 50 mg/ml) given intramuscularly or subcutaneously, once a day for 5 days.

- 0.2 ml (8 mg) Flagyl suspension (metronidazole) given orally once a day for 5 days.
- 0.08 ml Combivit injection given intramuscularly on day 1 & day 4 of catch-up.
- 0.04 ml ADE forte injection given intramuscularly on day 2 & day 5.
- No vitamin injection on day 3.
- Extra Enterodex (probiotic) & Ensure to be offered as often as possible.

For those animals with persistent severe watery diarrhoea, Ensure is given twice a day (approximately 5 ml morning and evening) to increase fluid intake and to replace any lost vitamins and minerals, as this liquid food has been shown to be more readily absorbed when given to humans suffering from Crohn's disease or colitis. Some animals particularly like the taste of ensure and it can be used to get the individual to take its daily medication.

2.8.2.3 Avoiding stress

Reduction of any stress is essential in maintaining the health of this species. They require a secure off-show area where there is minimal disturbance from both public and keeping staff. All husbandry routines must be kept to a minimum, and the enclosure must have sufficient space for the animal to be able to escape and hide when the area is being serviced, ideally allowing sufficient space within the enclosure for the animals to remain beyond their flight distance from people while the area is serviced.

Pied tamarins must also be housed away from conspecifics as they are very territorial and the presence of other breeding groups can have a detrimental effect on the health of individuals. It is an unnatural situation for animals to be constantly in close proximity to others outside their group. Also, where possible do not house both male and female single-sex groups in the same building, as their stability can be affected by the close proximity of members of the opposite sex.

Catching should be carried out only by an experienced carer and only when absolutely necessary. See section on "Capture, Handling and Transport".

2.8.2.4 Dietary requirements and access to UV light

Pied tamarins seem more prone than other callitrichid species to the effects of lack of UV light and vitamin D3, leading to rickets and osteomalacia. As a result, changes have been made to diet and management of pied tamarins at Durrell to counteract these problems.

Supplementation of D3 oil is very important in the winter months, but as this vitamin is not passed into the breast milk, infants will not benefit from this, so all autumn/winter birth infants MUST have access to UV lighting to prevent the onset of metabolic bone disorder. Preliminary studies of the effects of UV light on bone formation of tamarins are described in Lopez et al. (2001).

The two pairs of x-rays above show skeletal development of two juvenile tamarins, a healthy infant on the right, compared with the individual on the left, who was born and weaned during the colder months and shows de-mineralisation of the bones.

The two pairs of x-rays above show skeletal development of a healthy adult individual on the right, and on the left a tamarin suffering from poor development of the femur and humerus due to lack of exposure to UV light.

Morning feed (given at 08h30): All tamarins are provided with a monkey pellet – the brand used at Durrell is Skinners pellet, which appears to bear some similarities to the Mazuri New World monkey pellet. Many pellets have been tried in the past; the Skinners pellet is lower in protein and vitamin D3 oil than that of other manufacturers, but the tamarins seem to consume more of this pellet than the ones previously used and their diets are sufficiently supplemented with additional protein and D3 oil.

The pellet is soaked in water overnight with a small amount of honey added to improve the taste. Each animal is provided with approximately 30g of this pellet a day.

The tamarins are also provided with a banana puree, which is considered the easiest and most successful way of getting the following supplements into the diet. It is poured on the top of the pellets with every morning feed. The following recipe is for approximately 40 to 50 animals:

5/6 bananas
2 ml D3 oil during winter months, or if animals confined inside
Probiotic powder (1 scoop)
Aloe vera juice (approx 20 ml)

This is all blended together with a small amount of water to form a puree and approximately 15 ml is given to each individual per day. The probiotic powder is used to increase the beneficial bacteria in the gut. The aim of including aloe vera is to promote cell regeneration in the lining of the guts of individuals suffering from wasting.

Midday feed (given at 12h30): Due to the sensitive nature of pieds, especially the "wasting" individuals, it has been necessary to make some amendments to their fruit diet. Some fruits high in sugars or acidity tend to cause increased incidence of diarrhoea, for example oranges, grapes, kiwi and apples. These have been reduced or completely excluded from the diet. Noticeable improvements have been seen in the firmness of faeces but there has been no statistical evidence or firm data to confirm this. Banana is offered to pieds on a daily basis, plus at least one vegetable (e.g. sweet potato and carrots) and two to three other fruits, varied daily. Pomegranates have been suggested as having some beneficial effects for sufferers of irritable bowel syndrome, and papaya is also said to have beneficial effects on the stomach.

Protein is provided along with their fruit and forms approximately 30% by weight of the midday feeds. We have noted that pied tamarins, especially those suffering from wasting, are more likely to choose a protein item over a favourite fruit such as banana. Examples of protein items are ox-heart, egg (usually cooked, occasionally raw), cooked chicken and meaty cat food. Gum arabic is given to pieds occasionally as a treat, but with wasting individuals is can have detrimental effects on their faeces. Approximately 80 g of food is offered to each individual per day at this feed.
*Calcium lactate is sprinkled on the midday feed of lactating females.

Evening feed (given at 16h00): Each tamarin is fed a small piece of bread soaked in very dilute honey as a snack to ensure that carers can check them at the end of the day, plus approximately 10 wax-moth larvae and one or more locusts (hoppers) at every evening feed.

Food items as enrichment: Additional insects, for example mealworms and crickets, are sometimes offered at *ad hoc* intervals to tamarins during the afternoon. They are spread around the enclosure or put into enrichment devices, for example hollowed logs, or plastic crates hanging up high in the enclosure and filled with wood wool. Enrichment is a useful method of offsetting aggression in a group.

Mealworms can be detrimental to tamarins if given in large quantities as they have high phosphorus levels. This can impede calcium uptake, so wax-moth larvae, which are high in protein and fat, are the preferred choice at the evening feed.

2.9   Recommended (and planned) ex situ research

As shown in the literature review (see EAZA Callitrichidae TAG website), extensive *ex situ* research has been done on Callitrichidae. Many projects are currently ongoing (see below), involving a wide range of disciplines/subjects. Additional information is required in a number of areas to fill in obvious gaps or validate existing data, particularly where there are contradictory viewpoints. Section 2.9 highlights this, indicating appropriate areas for further research. Some of the questions raised may be addressed through the use of husbandry questionnaires, with a more in depth assessment of specific aspects carried out through research programmes.

Opportunistic sampling for future research is recommended. When the opportunity arises, serum (and liver tissue for genetic research) samples should be taken and stored at –20°C or below. This serum bank can be very helpful for further diagnostic procedure (reference, serology etc) and for various research works (see section 2.7).

2.9.1   Veterinary medicine

Yersinia pseudotuberculosis (see also section 2.7): At Pasteur in Lille, a novel anti-*Yersinia* mucosal vaccination strategy using recombinant lactic acid bacteria has been developed and tested in mice (Daniel et al., 2009). Thierry Petit and colleagues want to assess its potential for Callitrichidae. Michel Simonet is willing to test different routes for the inoculation of the vaccine and to do some more studies on different animals (guinea pigs, which are very sensitive to pseudoTB, for instance). More research is required to answer questions concerning antigenic presentation and delivery. We should not only think about *Y. pseudotuberculosis* – there are also many fatal infections of *Y. enterocolitica*. The post-mortem looks very similar (see also thesis by Pierre Grothmann, Magdeburg).

Protozoans are also a problem. Magdeburg Zoo has *Giardia* and *Entamoeba* intermittently in the emperor tamarin *S. imperator*. *Entamoeba histolytica* infections in captive monkeys in Belgian zoos have been recently reported (Levecke et al., 2007) and further research is required to fully assess the scope of the problem.

Trypanosoma cruzi and intestinal helminths infect wild golden lion tamarins and golden-headed lion tamarins (Monteiro et al. 2007). In an upcoming project, Lillian Silva Catenachi (BioBrasil, CRC, RZSA) will assess the prevalence in GHLTs as well as in domestic animals (potential sources for zoonoses; Chagas disease). It might be useful to expand trypanosoma research by Rafael Monteiro from wild into captive populations of lion tamarins (possible transfer through placenta).

2.9.2   Genetics

Continue research on species, subspecies taxonomy (red-bellied tamarin *Saguinus labiatus*; saddleback tamarin *Saguinus fuscicollis*; emperor tamarin *Saguinus imperator*; Rylands and Mittermeier, 2008).

Assess and compare genetic diversity in captive and wild populations (golden-headed lion tamarins, GHLTs, *Leontopithecus chrysomelas* in RZSA*; S. labiatus* in DPZ, Germany). In twenty years the captive population of GHLTs has grown well and has reached a size of about 200 animals in the EEP. It has been estimated that 97% of the genetic diversity has been retained. However, golden-headed lion tamarins were imported from Brazil in small groups. If these consisted of family groups, the current genetic variability in our captive stock might be severely overestimated. Using recently published microsatellite DNA markers (Galbusera and Gillemot, 2008) the RZSA will try to estimate the genetic relationship between the founders to improve our breeding schemes.

2.9.3   Hormonal studies

Contraception (see also section 2.4.7.2.3): new methods/product such as Suprelorin/Ovaban (GNRh-antagonist; used at IZW-Berlin) might allow more group stability (1 litter per year) and reversibility (advised by the AZA Wildlife Contraception Centre). In the USA (AZA) it is recommended for callitrichids (see http://www.stlzoo.org/downloads/CAGrecs2007revised#newworldmonkey) but is still in a testing phase. Studies are needed on the dosage and effects on callitrichids. It is recommended that all individuals on contraception be reported to the European Group on Zoo Animal Contraception EGZAC (www.egzac.org). EGZAC works in association with the American Association of Zoos and Aquariums Wildlife Contraception Center (AZA WCC).

Marmoset wasting syndrome (see e.g. Araújo de Moraes et al., 2007).

Research on stress management and cortisol levels in pied tamarins *S. bicolor* is ongoing at Durrell Wildlife Conservation Trust in Jersey. Pied tamarins are difficult to maintain in captivity, and in most collections, morbidity and mortality are high, the main health problems being wasting syndrome and metabolic bone disorders. The species' confrontational nature and its unique

responses to some situations continue to pose a challenge. Research therefore continues to be vital both in understanding this species' particular needs in captivity, and in planning conservation strategies in the wild which may include translocation and reintroduction. An investigation into stress levels was therefore initiated. It is clear from individual case studies that stressful events such as aggression within a group, a move to a new cage or introduction to a new cagemate, or repeated handling for medical treatment, give rise to increased cortisol levels.

Coloration change (SSP/ Thierry Petit, La Palmyre/ Sharon Redrobe, Bristol): Loss of pigment could be 1. metabolic (hormones, nutrition) or 2. genetic or 3. immune-mediated (e.g. Vitiligo, other syndromes reported in humans). Skin biopsies and histology research are recommended.

2.9.4. Behavioural research/enrichment

Behavioural research needed to improve management: How are subordinate females behaviourally repressed (see section 2.4.7.2.2)? What are the potential negative effects of being in a unisex group for a long time (see also section 2.4.7.3)?

Use of Clopixol in cotton-top tamarins *Saguinus oedipus*: At Zoo la Palmyre clopixol is used on a mother with a poor rearing history (Thierry Petit, pers. comm.). They have found that she rears when she receives the drug, but not when she isn't given it. They will continue to follow her in successive pregnancies to see whether she will learn natural rearing behaviour without the drug.

2.9.5. Nutrition

Diet (wild versus captive): Which morphological and nutritional characteristics determine the diet of GHLTs? In the wild, diet choice for GHLTs does not seem to be determined by morphological or nutritional characteristics of the fruits consumed. Rather, the main factor influencing diet seems to be the availability and density of the fruit species in time and space (Kristel De Vleeschouwer and Lillian Catenacci, pers. comm.).

Diet preference in captivity (Melissa Yaxley, Colchester, Bristol): A feed intake study, using continuous focal observation, food weight measurements and published food compositions, was carried out to assess the nutrient intakes of captive lion tamarins and the existence of food preferences when a heterogeneous diet is offered. There were clear preferences shown towards certain food items over others and diets selected by individuals were lacking in diversity. However, although differences did occur in individual nutrient intakes, a lack of quantitative data made it difficult to assess the diets being consumed by the tamarins. More research is necessary to replace suggested levels given with known levels appropriate for these species.

There is a need to assess individual intake of nutrients over longer time spans. (see: "The effect of vitamin D supplementation and UV exposure on the incidence of metabolic bone disorders in emperor tamarins *Saguinus imperator*". Clare Baker and Julian Wiseman, University of Nottingham and Jackie Hooley, Twycross Zoo) .

Diet composition, overweight and obesity (RZSA, WUR and Bristol): In many primates there is an effect of body condition on reproduction. Body condition itself can be affected by rearing in captivity. In this study we investigated these effects in GHLTs in Antwerp Zoo (limited data set). Body condition did increase over generations but no effect on reproduction was detected. Body weight increased with the use of melengestrol acetate implants. More data and analysis are needed. Current research in collaboration with Tjalling Huisman (WUR, NL).

There is a need to quantify water consumption (e.g. emperor tamarin, *S. imperator*).

Litter size in captivity: Research on the incidence of singletons, twins and triplets in callitrichids in captivity and if there is any correlation with generation level (time) in captivity, nutrition factors, other factors.

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