Captive Breeding Programmes for Nocturnal Prosimians

Anna Margaret Elvidge

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Abstract

Due to the nocturnal and arboreal nature of nocturnal prosimians field research on these species is limited. Maintaining populations in zoos provides an opportunity to increase our knowledge of these elusive species. This study aimed to update and contribute to the limited research on captive populations of nocturnal prosimians. The study consists of two parts. Part one aimed to identify the current European captive population of six nocturnal prosimian species (aye-aye, fat-tailed dwarf lemur, Goodman's mouse lemur, grey mouse lemur, grey slender loris and pygmy slow loris) and determine their demographic self-sustainability. To achieve this aim studbook data was analysed. The difference between birth and death rates, infant mortality rates, age structure and sex composition were investigated. The study concludes populations of aye-aye, fat-tailed dwarf lemur, grey slender loris and pygmy slow loris were not self-sustaining whereas Goodman's mouse lemur are self-sustaining and grey mouse lemur were found to have an increasing population trend. Part two focussed on the European captive population of pygmy slow loris and grey slender loris. This section sort to determine if husbandry methods affect breeding success. This involved conducting a survey of the current husbandry methods used in 20 European zoos. Statistical tests were carried out to determine if there was a correlation between institution breeding success and the husbandry methods used. The study concludes that there was a significant correlation between institution breeding success and the interval duration between cleaning the fixed enclosure furniture ($P=0.030$). Results also strongly suggested pygmy slow lorises housed with another species have a higher breeding success than those housed as a single-species exhibit.

Chapter One

1.0 Introduction

In the proposed study captive populations of nocturnal prosimians and their captive breeding programmes in European zoos will be investigated. The study plans to analyse captive population data to determine the long-term sustainability of these managed populations. The research also plans to carry out a survey of current husbandry methods used within European zoos for grey slender loris and pygmy slow loris to determine if captive management methods play a role in the breeding success of these species.

1.1 Wild animals in captivity

Exotic animals have been kept in captivity as part of collections for thousands of years (Hancocks 2010; Hosey *et al* 2009). Historically a collection of wild animals was considered as a sign of wealth, national pride and regal power for the amusement of the social elite (Hancocks 2010). Later, in the eighteen century public interest in exotic animals grew and saw the first travelling collections (known as menageries) appear in Western Europe (Hancocks 2010; Hosey *et al* 2009). The term 'zoo' was introduced in 1828 when London Zoo opened its doors in Regent's Park (Hancocks 2010; Hosey *et al* 2009). This marked the birth of the modern zoo, featuring elegant architectural design, it soon become a fashionable attraction. The popularity of this attraction inspired many cities in Western Europe to follow suit (Hancocks 2010) and resulted in a surge of zoos being built between 1830-1850 (Hancock 2010; Hosey *et al* 2009).

The first zoos to open to the public were generally regarded as places that provided public entertainment (Hancocks 2010; Hosey *et al* 2009; West and Dickie 2007). With little scientific knowledge of exotic animals, enclosure design was generally based on the needs of the public and with a view to be easily cleaned (Hancocks 2001). The 1920-30s saw captive wild animals often being kept in sparse concrete enclosures with metal bars to enable the public to view them clearly (Hancocks 2001). As scientific knowledge advanced a need for better welfare for zoo animals was highlighted (Holst and Dickie 2007; Hosey *et al* 2009). This brought about a change in the public perception of keeping wild animals in captivity and the 1970s saw the beginning of the animal rights movement (Donahue and Trump 2006). As

people started to become aware of the importance of animal welfare, public attendance to zoos started to decline (Hancocks 2001; Hosey *et al* 2009). To ensure their future survival these institutions needed to adapt to this change in public opinion (Hosey *et al* 2009). This was the beginning of the modern zoo as we know it today, an institution with a greater focus on animal welfare, conservation and the presence of more naturalistic exhibits suited to fulfil individual species specific requirements (Hancocks 2001, Miller *et al* 2003). The focus on conservation has since grown in many present day zoos and it has become a strong part of their constitution (Zimmermann *et al* 2007; Hosey *et al* 2009).

1.2 Conservation within zoos

In 1993 the 'World Zoo Conservation Strategy' (WZCS) was produced by the International Union of Zoo Directors of Zoological Gardens (IUDZG) (renamed WAZA in 2000) and the Conservation Breeding Specialist Group (CBSG) (IUDZG and CBSG 1993). This document was considered ground-breaking and suggested how zoos could play a role in conservation (IUDZG and CBSG 1993; Wallis 1997; Hosey *et al* 2009). It makes reference to the IUCN World Conservation Strategy and suggests ways zoos can support the strategy by implementing specific conservation methods (IUDZG and CBSG 1993). It promotes the use of captive breeding of endangered species, education and scientific research as ways they can play a role (IUDZG and CBSG 1993).

The current World Zoo and Aquarium Conservation Strategy, a document titled 'Building a Future for Wildlife', was released in 2005 (WAZA 2005). This document builds on the WZCS strategy, setting out conservation goals for zoos and makes recommendations of how they can be reached (WAZA 2005; Hosey *et al* 2009). The current strategy has a vision that zoos should incorporate conservation activities in all aspects of their work (WAZA 2005). Many zoos now exhibit a broad range of conservation activities to fulfil their conservation mission such as; captive breeding of endangered species, environmental education, scientific research and supporting *in-situ* conservation projects such as reintroduction programmes (Hutchins and Conway 1995; Baker, 2007; Hosey *et al* 2009; Lees and Wilcken 2009).

The addition of the term 'conservation' is now frequently seen within the mission statement of many zoos, indicating it is an integral part of its institution (Miller *et al* 2004). This inclusion to their mission statement has started to raise questions as to what role zoos actually play and the effectiveness of their conservation methods

(Miller *et al* 2004; Zimmermann *et al* 2007; Lee and Wilcken 2009). The vast array of methods used to convey conservation used by zoos has led to the proposal and discussion of a number of different evaluation techniques (Miller *et al* 2004; Stem *et al* 2005; Mace *et al* 2007; Lees and Wilcken 2009; Bowkett, 2010; Gussett and Dick 2010). Stem *et al* 2005 suggests that to evaluate the contribution to conservation effectively each method used by zoos requires a different approach (Stem *et al* 2005). They suggest zoos should work together to standardize their monitoring and evaluation techniques (Miller *et al* 2004; Stem *et al* 2005; Gussett and Dick 2010). The small size of conservation departments and the resources they allocate may also limit their contribution and could seriously affect the success of their methods (Miller *et al* 2004; Gusset and Dick 2010).

Studies evaluating the contribution zoos make to conservation show varying levels of success. Zoos had a promising start with the captive breeding of endangered species for reintroduction, helping the survival of wild populations of black-footed ferret (*Mustela nigripes*), California condor (*Gymnogyps californianus*) and Mauritius kestral (*Falco punctatus)* (Snyder *et al* 1996). However this method has also been discovered to have poor levels of success (Beck *et al* 1994; Snyder *et al* 1996; Bowkett 2009; Hosey *et al* 2009). A study carried out in the early nineties researching the success of these programmes found only 16 of 145 programmes to be successful (Beck *et al* 1994). In regard to the contribution zoos make to *in-situ* conservation Gussett and Dick (2010) found zoos are helping to improve the conservation status of threatened species and habitats in 113 projects throughout the world. It has been suggested that although many zoos are playing an active role in conservation they should increase this contribution (Snyder *et al* 1996; Gussett and Dick 2010) for instance; zoos could play a bigger part in education, research, captive populations, and supporting *in-situ* conservation projects (Snyder *et al* 1996; Gussett and Dick 2010).

1.3 Captive breeding

In order for zoos to carry out their vast array of conservation activities and to be seen as an advocacy for conservation it is vital for zoos to maintain a demographically and genetically healthy captive animal population (Lees and Wilcken 2009). Captive breeding programmes have allowed animal collections to consist mainly of captive-bred individuals, reducing the amount taken from the wild (Hosey *et al* 2009). The *ex-situ* conservation method of the captive breeding of threatened species was given great importance in the late 1980s when IUCN (World

Conservation Union) released a captive breeding policy document (IUCN 1987). This document asks all organisations world-wide that were maintaining captive wild animal populations to develop 'demographically self-sustaining populations of endangered species' (IUCN 1987). This recommendation was later reiterated in the World Zoo Conservation Strategy and the early 1990s saw a great number of species being recommended for this method (Snyder *et al* 1996; Bowkett 2009).

Soulè *et al* 1986 conducted one of the first studies to propose that zoological institutions need to work cooperatively to maintain genetically and demographically healthy populations. Members of the World Association of Zoos and Aquariums (WAZA) now manage captive populations on a global, regional and institutional level (BIAZA 2005; Hosey *et al* 2009). On a regional level current management of captive populations within Britain and Ireland consists of a strong collaboration with all European zoological institutions who are members of the European Association of Zoos and Aquaria (EAZA) (BIAZA 2005). Successful management of captive populations relies on good cooperation between EAZA institutions to allow animals to be exchanged for breeding (Hosey *et al* 2009). Populations are managed as a metapopulation, although members of the same species are held in many institutions they are considered connected and managed as one single population (Tilson *et al* 1997; BIAZA, 2005; Hosey *et al* 2009).

Within European institutions the captive breeding of threatened species is managed through two levels; the European Endangered Species programme (EEPs) and European Studbooks (ESBs) (BIAZA 2005). EEPs are intensive management programmes run by a coordinator and supported by a committee of species experts (BIAZA 2005; Hosey *et al* 2009). Based on the data they collect these programmes make recommendations for breeding and transferring individuals between institutions (BIAZA 2005; Hosey *et al* 2009). ESBs are less intensive and involve maintaining a record of a species captive history (Wiese and Hutchins 1997). Information on the birth, death, father, mother, and transfers between institutions are documented on each individual within a population (Wiese and Hutchins 1997; BIAZA 2005). This information is documented and maintained by a single studbook keeper (Wiese and Hutchins 1997; BIAZA 2005). Studbooks play a vital role in both levels of captive breeding programmes (Wiese and Hutchins 1997; Glatson 2001). Keeping records of all individuals allows the correct management to be applied in order to maintain a genetically and demographically healthy population (Wiese and Hutchins 1997; Glatson 2001).

1.4 Self-sustaining populations

In order for zoological institutions to maintain captive-bred populations over defined amounts of time, captive populations need to be self-sustaining (Hosey *et al* 2009; Lees and Wilcken 2009). For a population to be considered self-sustaining the number of births must be equal to or be greater than the number of deaths each year (Hosey *et al* 2009; Riewald *et al* unpublished). EAZA's current criteria for the genetic self-sustainability of captive populations are based on the Soulè *et al* (1986) recommendations. EAZA aims to 'maintain 90% genetic diversity of the wild population in the captive population for 100 years' (Riewald *et al* unpublished).

Research into the sustainability of captive breeding programmes has revealed problems (W.R.I. *et al* 1992; Snyder *et al* 1996). In the early 1990s a study on 274 captive breeding programmes found that only 26 could be considered to be self-sustaining (W.R.I. *et al* 1992). Magin *et al* (1994) also found that of all captive populations of threatened species only 17% were classed as self-sustaining. Studies carried out on a broad range of taxa ten years later, 20 years on since the IUCN Captive Breeding policy document, indicate the sustainability of captive populations is still poor (Baker 2007; Lees and Wilcken 2009; Riewald *et al* unpublished). Riewald *et al* (unpublished) conducted a study on 177 captive mammal populations that are held within EAZA institutions. This research revealed that only 13 of the 177 fulfilled the set criterion for being sustainable (Riewald *et al* unpublished). However, this was a rapid study to determine the general state of mammal populations (Riewald *et al* unpublished). Populations indicated as failing any criterion requires further analysis to determine the accuracy of the results (Riewald *et al* unpublished).

1.5 Captive primate populations

Studies conducted on the condition of all captive primate populations are limited. Riewald *et al* (unpublished) rapid study on EAZA mammal populations included 56 primate populations, only six fulfilled all categories to be considered self-sustaining. This result suggests the need for further analysis of all primate populations (Riewald *et al* unpublished). Studies that took place on individual populations reveal problems (Glatson 2001; Kaumanns *et al* 2001; Schwitzer and Kaumanns 2009; Ange-Van Heugten 2010). The world-wide captive population of woolly monkeys *Lagothrix spp*. showed an 11% decrease between 1990-2005 (Ange-Van Heugten *et al* 2010). The captive population of European lion-tailed macaques (*Macaca silenus*) at first

glance appears to be doing well with an increased population of 90-200 individuals from 1989-1998 (Kaumanns *et al* 2001). Further analysis revealed that the younger reproductively active generation (aged 4-15 yrs) presents a low birth rate and high infant mortality putting the future of this population at risk (Kaumanns *et al* 2001).

The amount of primate births in captivity is considered low in a number of species (Glatston 2001; Kaumanns *et al* 2001, 2008; Schwitzer and Kaumanns 2009; Ange-Van Heugten 2010). European populations of captive grey mouse lemurs (*Microcebus murinus*) saw a significant decline between the years 1990-94 (Glatson 2001). Captive populations of black-and-white ruffed lemurs (*Varecia variegata*), woolly monkeys, lion-tailed macaques have also exhibited high infant mortality rates (Kaumanns *et al* 2001; Schwitzer and Kaumanns 2009; Ange-Van Heugten *et al* 2010).

A key part of maintaining captive populations of exotic animals is good management (Baker 2007). The science behind managing captive populations has been well researched and tested (Lees and Wilcken 2009). A study by Lees and Wilcken (2009) suggests that the communication of this research to zoos is poor and advances in scientific research are not being represented within management plans (Lees and Wilcken 2009). Kaumanns *et al* (2008) suggest that low growth rates are linked to their captive environment and lack of freedom to express natural behaviours. A study on captive woolly monkeys reveal causes of death within their population relate to nutritional related diseases such as obesity and diabetes mellitus (Ange-Van Heugten *et al* 2010). Schwitzer and Kaumanns (2009) found an increase in female body weights of black-and white ruffed lemurs over four generations. Conducting correct management techniques to manage changes in life history traits could prevent future loss of genetic viability (Schwitzer and Kaumanns 2009).

1.6 Nocturnal prosimians

Nocturnal prosimians are classified as more distantly related to humans due to their anatomical features (Cowlishaw and Dunbar 2000). Prosimian primates are made up of three primate infraorders; lemurs, galagos-loris-potto group and tarsiers (Cowlishaw and Dunbar 2000; Campbell *et al* 2007). However, tarsiers have also been found to exhibit characteristics associated with anthropoid primates (a primate group more closely related to humans) (Cowlishaw and Dunbar, 2000; Campbell *et al* 2007). Anthropoid traits exhibited in tarsiers such as a dry rhinarium have caused

discussion as to what primate group tarsiers belong (Cowlishaw and Dunbar 2000; Campbell *et al* 2007). Scientists have since classified primates into the following two groups; Strepsirhini (lemurs, lorises and galagos) and Haplorhini (anthropoids and tarsiers) (Cowlishaw and Dunbar 2000; Campbell *et al* 2007).

Due to the nocturnal and arboreal nature of nocturnal prosimians field research is hard as individuals are difficult to follow in the wild (Iwano 1991; Sterling and McCreless 2006). Due to the limited research on these species approximately 39% of this group of primates have a current IUCN Red List status of Data Deficient (DD) (Table 1, 2) (Campbell *et al* 2007; IUCN 2011).

Table 1: List of 114 nocturnal prosimian species, their current IUCN Red List status and European breeding programme (Campbell *et al* 2007; EAZA 2010; Johann 2010; IUCN, 2011).

Infraorder	Latin Name	Common Name	IUCN Red List Status	European Breeding Programme
Lemur	*Cheirogaleus medius*	Western fat-tailed dwarf lemur	LC	ESB
Lemur	*Cheirogaleus major*	Geoffroy's dwarf lemur	LC	No
Lemur	*Cheirogaleus crossleyi*	Furry-eared dwarf lemur	DD	No
Lemur	*Cheirogaleus ravus*	Greater Iron-grey dwarf lemur	DD	No
Lemur	*Cheirogaleus adipicaudatus*	Southern fat-tailed dwarf lemur	DD	No
Lemur	*Cheirogaleus sibreei*	Sibree's dwarf lemur	DD	No
Lemur	*Cheirogaleus minusculus*	Lesser Iron-grey dwarf lemur	DD	No
Lemur	*Allocebus trichotis*	Hairy-eared dwarf lemur	DD	No
Lemur	*Mirza coquereli*	Coquerel's giant mouse lemur	NT	No
Lemur	*Mirza zaza*	Northern giant mouse lemur	DD	No
Lemur	*Microcebus arnholdi*	Arnhold’s mouse lemur	Not Listed	No
Lemur	*Microcebus berthae*	Madame berthe's mouse lemur	E	No
Lemur	*Microcebus bongolavensis*	Bongolava mouse lemur	DD	No
Lemur	*Microcebus danfossorum*	Danfoss' mouse lemur	DD	No
Lemur	*Microcebus griseorufus*	Grey-brown mouse lemur	LC	No
Lemur	*Microcebus jollyae*	Jolly's mouse lemur	DD	No
Lemur	*Microcebus lehilahytsara*	Goodman's mouse lemur	DD	ESB
Lemur	*Microcebus macarthurii*	Anjiahely mouse lemur	Not Listed	No
Lemur	*Microcebus mamiratra*	Claire's mouse lemur	DD	No
Lemur	*Microcebus margotmarshae*	Margot marsh’s mouse lemur	Not Listed	No
Lemur	*Microcebus mittermeieri*	Mittermeier’s mouse lemur	DD	No
Lemur	*Microcebus murinus*	Grey mouse lemur	LC	ESB
Lemur	*Microcebus myoxinus*	Peters’ mouse lemur	DD	No

Lemur	*Microcebus ravelobensis*	Golden-brown mouse lemur	E	No
Lemur	*Microcebus rufus*	Rufous mouse lemur	LC	No
Lemur	*Microcebus sambiranensis*	Sambirano mouse lemur	E	No
Lemur	*Microcebus simmonsi*	Simmons' mouse lemur	DD	No
Lemur	*Microcebus tavaratra*	Tavaratra mouse lemur	E	No
Lemur	*Phaner electromontis*	Montagne D' Ambre fork-marked lemur	V	No
Lemur	*Phaner furcifer*	Masoala fork-marked lemur	LC	No
Lemur	*Phaner pallescens*	Pale fork-marked lemur	LC	No
Lemur	*Phaner parienti*	Sambirano fork-marked lemur	V	No
Lemur	*Avahi betsileo*	Betsileo woolly lemur	DD	No
Lemur	*Avahi cleesei*	Bemaraha woolly lemur	E	No
Lemur	*Avahi laniger*	Gmelin's woolly lemur	LC	No
Lemur	*Avahi meridionalis*	Southern woolly lemur	DD	No
Lemur	*Avahi mooreorum*	Moore's woolly lemur	Not Listed	No
Lemur	*Avahi occidentalis*	Lorenz Von Liburnau's woolly lemur	E	No
Lemur	*Avahi peyrierasi*	Peyrieras' woolly lemur	DD	No
Lemur	*Avahi ramanantsoavanai*	Ramantsoavana's southern woolly lemur	DD	No
Lemur	*Avahi unicolor*	Sambirano woolly lemur	DD	No
Lemur	*Daubentonia madagascariensis*	Aye-aye	NT	EEP
Lemur	*Lepilemur aeeclis*	Antafia sportive lemur	DD	No
Lemur	*Lepilemur ahmansonorum*	Ahmanson's sportive lemur	DD	No
Lemur	*Lepilemur ankaranensis*	Ankarana sportive lemur	E	No
Lemur	*Lepilemur betsileo*	Betsileo sportive lemur	DD	No
Lemur	*Lepilemur dorsalis*	Grey's sportive lemur	DD	No
Lemur	*Lepilemur edwardsi*	Milne-edwards's sportive lemur	V	No
Lemur	*Lepilemur flueretae*	Fleurete's sportive lemur	DD	No
Lemur	*Lepilemur grewcockorum*	Grewcock's sportive lemur	DD	No
Lemur	*Lepilemur hubbardorum*	Hubbard's sportive lemur	DD	No
Lemur	*Lepilemur jamesorum*	James' sportive lemur	DD	No
Lemur	*Lepilemur leucopus*	White-footed sportive lemur	DD	No
Lemur	*Lepilemur microdon*	Small-toothed sportive lemur	DD	No

Lemur	*Lepilemur milanoii*	Daraina sportive lemur	DD	No
Lemur	*Lepilemur mittermeieri*	Mittermeier's sportive lemur	DD	No
Lemur	*Lepilemur mustelinus*	Weasel sportive lemur	DD	No
Lemur	*Lepilemur otto*	Otto's sportive lemur	DD	No
Lemur	*Lepilemur petteri*	Petter's sportive lemur	DD	No
Lemur	*Lepilemur randrianasoloi*	Randrianasolo's sportive lemur	DD	No
Lemur	*Lepilemur ruficaudatus*	Red-tailed sportive lemur	DD	No
Lemur	*Lepilemur sahamalazensis*	Sahamalaza peninsula sportive lemur	DD	No
Lemur	*Lepilemur scottorum*	Masoala sportive lemur	Not Listed	No
Lemur	*Lepilemur seali*	Seal's sportive lemur	DD	No
Lemur	*Lepilemur septentrionalis*	Sahafary sportive lemur	CE	No
Lemur	*Lepilemur tymerlachsonorum*	Nosy Be sportive lemur	DD	No
Lemur	*Lepilemur wrightae*	Wright's sportive lemur	DD	No
galagos-loris-potto	*Loris tardigradus*	Grey slender loris	LC	No
galagos-loris-potto	*Loris tardigradus*	Red slender loris	E	EEP
galagos-loris-potto	*Nycticebus bengalensis*	Bengal slow loris	V	No
galagos-loris-potto	*Nycticebus coucang*	Greater slow loris	V	No
galagos-loris-potto	*Nycticebus javanicus*	Javan slow loris	E	No
galagos-loris-potto	*Nycticebus menagensis*	Bornean slow loris	V	No
galagos-loris-potto	*Nycticebus pygmaeus*	Pygmy slow loris	V	EEP
Tarsier	*Tarsius bancanus*	Horsfield’s tarsier	V	No
Tarsier	*Tarsius dianae*		Not Listed	No
Tarsier	*Tarsius lariang*	Lariang tarsier	DD	No
Tarsier	*Tarsius pelengensis*	Peleng tarsier	E	No
Tarsier	*Tarsius pumilus*	Pygmy tarsier	DD	No
Tarsier	*Tarsius sangirensis*	Sangihe tarsier	E	No
Tarsier	*Tarsius synricta*	Philippine tarsier	NT	No
Tarsier	*Tarsius spectrum*	Spectral tarsier	Not Listed	No
Tarsier	*Tarsius tarsier*	Spectral tarsier	V	No
Tarsier	*Tarsius dentatus*	Dian's tarsier	V	No
Tarsier	*Tarsius wallacei*	Wallace’s tarsier	Not	No

			Listed	
galagos-loris-potto	*Galagoides demidovii*	Demidoff's dwarf galago	LC	No
galagos-loris-potto	*Galagoides thomasi*	Thomas's dwarf galago	LC	No
galagos-loris-potto	*Galagoides cocos*	Kenya coast galago	LC	No
galagos-loris-potto	*Galagoides rondoensis*	Rondo dwarf galago	CE	No
galagos-loris-potto	*Galagoides zanzibaricus*	Zanzibar/udzungwa galago	LC	No
galagos-loris-potto	*Galagoides granti*	Grant's lesser galago	LC	No
galagos-loris-potto	*Galagoides orinus*	Mountain dwarf galago	NT	No
galagos-loris-potto	*Galagoides nyasae*	Malawi galago	DD	No
galagos-loris-potto	*Galagoides sp. nov. 1*	Kalwe lesser galago	Not Listed	No
galagos-loris-potto	*Galagoides sp. nov. 2*	Mt. Thyolo lesser galago	Not Listed	No
galagos-loris-potto	*Galagoides sp. Nov. 3*	Rungwe dwarf galago	Not Listed	No
galagos-loris-potto	*Galago gallarum*	Somali lesser galago	LC	No
galagos-loris-potto	*Galago moholi*	Southern lesser galago	LC	ESB
galagos-loris-potto	*Galago matschiei*	Spectacled lesser galago	LC	No
galagos-loris-potto	*Galago senegalensis*	Northern lesser galago	LC	ESB
galagos-loris-potto	*Euoticus elegantulus*	Southern needle-clawed galago	LC	No
galagos-loris-potto	*Euoticus pallidus*	Northern needle-clawed galago	LC	No
galagos-loris-potto	*Sciurocheirus gabonensis*	Gabon allen's galago	LC	No
galagos-loris-potto	*Sciurocheirus alleni*	Allen's galago	LC	No
galagos-loris-potto	*Sciurocheirus sp. Nov.*	Malande squrriel galago	Not Listed	No
galagos-loris-potto	*Otolemur garnettii*	Small-eared greater galago	LC	No
galagos-loris-potto	*Otolemur crassicaudatus*	Thick-tailed greater galago	LC	No
galagos-loris-potto	*Otolemur monteiri*	Silvery greater galago	Not Listed	No
galagos-loris-potto	*Otolemur sp. Nov.*	Mwera (pygmy) greater galago	Not Listed	No

galagos-loris-potto	*Perodicticus potto*	Western potto	LC	No
galagos-loris-potto	*Perodicticus potto ssp. edwardsi*	Central potto	LC	No
galagos-loris-potto	*Perodicticus potto ssp. ibeanus*	Eastern potto	LC	No
galagos-loris-potto	*Arctocebus aureus*	Golden angwantibo	LC	No
galagos-loris-potto	*Arctocebus calabarensis*	Calabar angwantibo	LC	No

Table 2: Total number of nocturnal prosimian species in each IUCN Red List category (Campbell *et al* 2007; IUCN 2011).

IUCN Red List Status	**Total No. of Each IUCN Red List Status**	**Percentage (%) of Total**
Not Listed (NL)	14	12.29
Data Deficient (DD)	44	38.59
Least Concern (LC)	29	25.44
Near Threatened (NT)	4	3.51
Vulnerable(V)	10	8.77
Endangered (E)	11	9.65
Critically Endangered (CE)	2	1.75
Total	**114**	**100.00**

The database on captive animal populations held within the International Species Information System (ISIS) report 18 of the 114 nocturnal prosimian are held within European institutions (ISIS 2011). Only eight of these species are currently part of managed breeding programmes (Table 1) (EAZA 2010; Johann 2010). These populations are currently managed within EAZA institutions primarily for their education and conservation value (Johann 2010). Maintaining these populations in zoos will allow the opportunity to increase our scientific knowledge of these elusive species (Baker 2007; Hosey *et al* 2009). This additional knowledge could help increase success in conserving their wild counterparts (Baker 2007; Martin and Bateson, 2007; Hosey *et al* 2009).

Research focusing primarily on the sustainability of nocturnal prosimian populations in captivity is extremely limited. A study carried out ten years ago on captive the grey mouse lemur (*Microcebus murinus*) held within European institutions revealed

the population to have low genetic variability with 75% of the population considered to be inbred (Glatson 2001). In this same study *M. murinus* was reported to be the only small nocturnal Malagasy prosimian species in captivity with the potential of a future viable population (Glatson 2001). A recent study by Riewald *et al* (unpublished) on EAZA mammal populations only included two nocturnal prosimians within its study of 117 populations. Results from this study reported that the population of both aye-ayes and grey slender loris contain less than 50 individuals, have low growth rates and have less than 30 known founders within their population. Failing three sustainability categories out of five stresses the need for further analysis of these populations (Riewald *et al* unpublished). Kaumanns *et al* (2008) suggested that the captive populations of primates could suffer similar low long-term survival rates as small population fragments in the wild.

Researching the demographic and genetic health of captive nocturnal prosimian populations would provide valuable information into the long-term viability of these populations (Baker 2007). Captive population data collected on the nocturnal prosimians within European zoos would also provide a current record of what animals are currently held within these institutions. Increasing our knowledge on the current population would allow genetic diversity within the populations to be better managed (Baker 2007).

1.7 Aims and objectives

This study aims to update and contribute to the limited research looking specifically at captive populations of nocturnal prosimians. The first part of the study aims to identify the current European captive population and determine their demographic self-sustainability. A population is considered demographically self-sustainable if, in general, the number of births is as high, or higher than the number of deaths (Riewald *et al* unpublished). The second part of this study will focus on the European captive population of pygmy slow loris and grey slender loris and the husbandry methods currently used on these species. This section aims to determine if husbandry methods affect breeding success in these species.

Objectives are:

- To construct a database on all captive populations of nocturnal prosimians that are part of breeding programmes within European zoological institutions through the retrieval of current studbook data.
- To determine if the populations are demographically self-sustaining by analysing data on births and deaths.
- To conduct a survey of the husbandry methods used by European zoological institutions for pygmy slow loris and grey slender loris.
- To determine if current husbandry methods affect the breeding success of captive pygmy slow loris and the grey slender loris by statistically analysing institution breeding success against husbandry data.
- To make recommendations for possible improvements in zoo policies regarding the breeding of nocturnal prosimian species.

Part 1

Chapter Two

2.0 Literature review

2.1 Captive breeding programmes for nocturnal prosimians

2.1.1 Taxon Advisory Groups

Taxon Advisory Groups (TAGs) have been set up in each regional zoo association (e.g. European Association for Zoos and Aquaria) to determine which species would benefit the most from captive breeding programmes (Porton 1995, Hosey *et al* 2009, Wiese and Hutchins 1997). A number of different TAGs within each region focus on specific taxonomic groups (e.g. prosimians, great apes, canids) (Rees 2011).Within the European Association of Zoos and Aquaria (EAZA) there are currently forty-two TAGs (Rees, 2011). Members of the TAG consist of a group of individuals from a variety of different backgrounds (e.g. zoological institutions, university, private citizens) with different fields of expertise (e.g. veterinary, nutrition, genetics) (Wiese and Hutchins 1997, Hosey *et al* 2009, Rees 2011). Additional to these individuals, studbook keepers for the relevant taxa are considered automatic members of the relevant TAG (Wiese and Hutchins 1997).

Each regional TAG has the responsibility of developing a document known as a Regional Collection Plan (RCP) (Porton 1995, Wiese and Hutchins 1997). This document recommends specific species for captive management programmes, the level of management at which these species should be managed (European Endangered Species Programmes or European StudBooks) and the primary role the captive population should play within the institution (e.g. education, conservation) (Porton 1995, Wiese and Hutchins 1997, Rees 2011). In order to determine which species/subspecies should be recommended, each are carefully evaluated (Wiese and Hutchins 1997, Hosey *et al* 2009, Rees 2011). Taxa are evaluated using a number of different factors; these include conservation status, current captive status, educational value and space requirements (Wiese and Hutchins 1997, Hosey *et al* 2009, Rees 2011).

The published RCPs are important documents used by individual zoological institutions to help select species for their collections (Wiese and Hutchins 1997,

Hosey *et al* 2009, Rees 2011). The first RCP to be published by the Prosimian TAG for the American Zoo and Aquarium Association (AZA) occurred in 1993 (Zeeve and Porton 1997).The latest RCP for the EAZA Prosimian TAG was published in 2010 (Johann 2010). This document recommends the following nocturnal species for captive breeding programmes and the main role of the captive population.

Table 3: Nocturnal Prosimian species recommended by the EAZA prosimian TAG for captive breeding programmes (Johann 2010).

Species (Common name)	**Species (scientific name)**	**Primary role(s)/ functions for population**
grey mouse lemur	*Microcebus murinus*	Education
Goodmann's mouse lemur	*M. lehilahytsara*	Education, Conservation
fat-tailed dwarf lemur	*Cheirogaleus medius*	Education
aye-aye	*Daubentonia madagascariensis*	Education
moholi galago	*Galago moholi*	Education
Senegal galago	*G. senegalensis*	Education
pygmy slow loris	*Nycticebus pygmaeus*	Education, Conservation
slender loris	*Loris tardigradus*	Education, Conservation

2.1.2 The importance of studbooks

Although the less intensive of two EAZA captive management programmes, European StudBooks (ESBs) are considered an essential tool for carrying out an organised breeding programme (Fitch-Snyder 1995, Glatston 2001, Hosey *et al* 2010, Rees 2011). This document is an historical inventory of all individual animals that make up a captive population (Fitch-Snyder 1995). They are maintained by a studbook keeper, this individual is usually associated with a zoological association or university (Fitch-Snyder 1995). The studbook keepers' role is to collate historical and current population data from all institutions that currently keep or have kept the species in the past (Ballou *et al* 2010). These records can be kept on a regional (European) or international level (Wiese and Hutchins 1997).

In order to maintain records on each individual within a captive population of wild animals, each individual is assigned a unique identification number (studbook number) (Wiese and Hutchins 1997). Detailed information is then recorded on this individual, which includes: birth and death date, capture date (if taken from the wild), parents, offspring, current location (zoological institute), past locations and dates they were re-located (Wiese and Hutchins 1997). Studbook keepers also record any other data about the individual that is thought relevant such as cause of death and abortions (Fitch-Snyder 1995, Pers.Obs).

The concept of studbooks was first developed in 1791 to record details on individuals within domestic horse collections (Bingaman Lackey 2010, Rees 2011). The use of studbooks in zoological collections did not occur until the 20th century and these records were not considered as an essential part of zoo management until 1965 (Bingaman Lackey 2010, Rees 2011). Before this time it was thought that populations of wild animals were in infinite supply and captive populations did not need to be self-sustaining (Bingaman Lackey 2010). The publication of the first studbook for wild animals kept in zoos was triggered by the extinction of two subspecies of European bison (*Bison bonasus bonasus, B. b. causcasicus*), which was hunted to extinction in the 1920-1930s (Bingaman Lackey 2010). The zoo community decided to take action to ensure the captive population of European wild bovid remained healthy and self-sustaining (Bingaman Lackey 2010, Rees 2011). This action involved setting up a studbook to monitor the population (Bingaman Lackey 2010, Rees 2011). This studbook was published in 1932 and was the first of its kind for recording data on zoo animals (Bingaman Lackey 2010). After this publication, studbooks slowly started to be developed for other species whose wild populations were threatened with a similar fate (Bingaman Lackey 2010).

EAZA's current criteria for the genetic self-sustainability of captive populations are based on Soulè *et al* (1986) recommendations. EAZA aims to 'maintain 90% genetic diversity of the wild population in the captive population for 100 years' (Riewald *et al* unpublished). In order to maintain a captive population that is genetically healthy, the population needs to retain the genetic diversity of its founder population (Ballou *et al* 2010). To remain also demographically healthy the size of the population needs to be large enough that extinction is voided if a catastrophic event were to occur (e.g. disease) (Ballou *et al* 2010). Unfortunately the lack of record keeping in animal collections prior to the 1960s has resulted in missing historical data on

captive populations (Bingaman Lackey 2010). Therefore studbook keepers have often found data on the founders and origin of a captive population difficult to obtain (Bingaman Lackey 2010). This missing data has made it hard for studbooks keepers to manage particular captive populations genetically (Bingaman Lackey 2010).

In order to manage a population successfully to ensure it is genetically and demographically healthy it is critical to maintain good quality studbook records (Wiese and Hutchins 1997, Bingaman Lackey 2010). Good quality studbook data not only helps to manage the population genetically to prevent inbreeding it also allows the data to be correctly analysed (Fitch-Snyder 1995, Wiese and Hutchins 1997). This data can determine important life history information on a population such as average litter sizes, infant mortality, generation lengths, birth seasons and reproductive success (Fitch-Snyder 1995, Wiese and Hutchins 1997). It is therefore an important tool that helps zoo managers to monitor the development of a captive population (Glatston 2001).

Literature relating to the establishment of studbooks for captive nocturnal prosimians is found to be limited (Glatston 2001). Glatston (2001) reported that studbooks for grey mouse lemur (*M.murinus*), Coquerels giant mouse lemur (*Mirza coquereli)* and fat-tailed dwarf lemur (*Cheirogaleus medius*) were first set up in 1994.

2.2 Nocturnal prosimians in captivity

Captive nocturnal prosimians are often housed within an indoor nocturnal animal house exhibit (Carroll and Beattie 1993). Zoos first started developing these nocturnal habitats in the 1950s, with the world's first opening in 1953 at Bristol Zoo Gardens in Bristol, England (Gold 1997, Hosey *et al* 2009). The development of these exhibits saw dimmed red lighting being used within enclosures for the first time allowing visitors to view the nocturnal animals in the dark (Gold 1997). This experimental lighting idea gave way to the concept of using a reverse lighting schedule within the animal house to simulate night-time during daylight hours allowing visitors to view the animals at their most active (Gold 1997, Hosey *et al* 2009). Many zoological institutions around the world (Duke Lemur Center in North Carolina, U.S.A; Durrell Wildlife Conservation Trust in Jersey, Channel Islands; and London Zoo in London, England) have adopted this lighting method to exhibit their

populations of nocturnal species (Wright *et al* 1987, Carroll and Beattie 1993, Gold 1997).

Captive populations of the nocturnal species recommended by the EAZA Prosimian TAG for breeding programmes (Table 3) have varying captive life histories within zoological institutions. The details of each of these primate families are described below.

2.2.1 Mouse lemurs in captivity

Mouse lemurs (genus *Microcebus*) are endemic to Madagascar and inhabit a range of habitats from dry deciduous forests to rainforests (Mittermeier *et al* 2010). They are considered to be the world's smallest living primates (Wrogemann and Glatston 2001, Yoder *et al* 2000, Mittermieier *et al* 2010) weighing between 30-87g and measure between 23-29 cm (including tail) in length (Mittermieier *et al* 2010). Up until the '90s it was thought that only two species of the genus *Microcebus* existed (grey mouse lemur *M. murinus*, and Rufous mouse lemur *M. rufus)* (Yoder *et al* 2000, Mittermieier *et al* 2010). However in recent years mouse lemur research has greatly increased (Yoder *et al* 2000; Mittermieier *et al* 2010) and to date 18 recognised species of *Microcebus* have been identified (Mittermieier *et al* 2010).

The grey mouse lemur has been found to breed well in captivity (Glatston, 2001). Mouse lemurs reach sexual maturity within their first year of life (Wrogemann and Glatston, 2001; Mittermeier *et al* 2010) and are considered to have the shortest gestation length of any primate (62 days) (Wrogemann *et al* 2001). In the wild they live in social groups and have been found to exhibit a multi-male/multi-female mating system (Wrogemann *et al* 2001, Eberle and Kappeler 2004, Schmelting *et al* 2007, Mittermeier *et al* 2010). The genus has been found have highly seasonal reproduction, with female in oestrous between February and September (Wrogemann *et al* 2001). Female mouse lemurs give birth up to twice a year and often have twins (Wrogemann and Glatston, 2001; Mittermeier *et al* 2010). All these factors have led the species to become the subject of many scientific studies on seasonal biology and reproduction (Wrogemann and Glatston 2001).

In order to help monitor the status of small nocturnal Malagasy prosimians populations in captivity a European studbook for small nocturnal Malagasy prosimians was established in 1994 (Glatston 2001). This studbook consisted of data on three different species of nocturnal lemur: grey mouse lemur (*M. murinus*),

Coquerels giant mouse lemur (*Mirza coquereli)* and fat-tailed dwarf lemur (*Cheirogaleus medius*) (Glatston 2001).

Studies looking at the status of these captive populations are found to be limited (Glatston 2001). A single study by Glatston (2001) took place over ten years ago and found the grey mouse lemur to be the only population with a big enough captive population size to carry out a meaningful analysis (Glatston 2001). An analysis of this population revealed that the captive population had been experiencing a decline since 1994, 75% of the individuals were inbred and there was a significant decline in the number of births (Glatston 2001). This decline was found to be the result of a combination of factors: the number of institution's breeding the species had decreased; the population was suffering with effects from the inbreeding, which was reducing reproductive output (Glatston 2001). Glatston (2001) stresses the need to introduce new founders within the population in order to protect the future genetic viability of this population.

2.2.2 The Aye-Aye in Captivity

The aye-aye (*Daubentonia madagascariensis*) is a species of lemur; like all lemurs this species is endemic to the island of Madagascar (Winn 1989, Carroll and Haring 1994, Mittermeier *et al* 2010). After much debate the species was scientifically classified under the order of Primate (Sterling 1994). The debate regarding the aye-ayes classification occurred due to a unique array of adaptations exhibited by the species. These include: highly mobile ears, elongated filiform middle digits, continually growing anterior teeth, inguinal mammary glands and a bushy tail longer than its body (Sterling 1994, Quinn and Wilson 2004, Mittermeier *et al* 2006). These adaptations also led to the species being classified within its own separate genus, *Daubentonia*, in the family Daubentoniidae*,* of which it is the only living member (Simons 1994, Sterling 1994, Quinn and Wilson 2004).

Although thought to be the most widely distributed of all the lemurs species they are found to only occur in small numbers (Mittermeier *et al* 2006). Once classified as 'Endangered' under the IUCN Red List, the species has since been re-classified as 'Near Threatened' with a declining population (Mittermeier *et al* 2006, IUCN 2011). However, this re-classification is disputed by Mittermeier *et al* (2010), who suggest this species should be re-classified back into the 'Endangered' category.

Published literature on the aye-aye states that the first attempts to maintain this species in captivity outside Madagascar occurred from 1862 (Winn 1989, Carroll and Haring 1994). However these first attempts were not greatly successful with many individuals either dying in transport or shortly after arrival (Winn 1989, Carroll and Haring 1994). It was not until 1986 that a larger number of individuals were exported resulting in 19 wild caught individuals being successfully exported to western countries (Carroll and Beattie 1993, Carroll and Haring 1994). These individuals were exported to three institutions; Durrell Wildlife Conservation Trust (formerly Jersey Wildlife preservation Trust), Jersey, Channel Islands; Vincennes Zoo, Paris, France and Duke Lemur Center (formerly Duke University Primate Center), Durham, USA (Carroll and Beattie 1993, Carroll and Haring 1994).

This event supplied an opportunity to increase the knowledge base of this unique species (Winn 1989) and resulted in a great number of the studies taking place within the late eighties to mid-nineties (Feistner and Carroll 1995). The first recorded captive birth that occurred outside Madagascar took place at the Duke Lemur Center (DLC) in April 1992; this individual was conceived in the wild (Beattie *et al* 1992). In August 1992, the first captive-bred individual was successfully born at Durrell Wildlife Conservation Trust (DWCT) (Beattie *et al* 1992). This captive-bred birth was successfully followed by two further births at DLC in the same year (Carroll and Beattie, 1993). These births saw the start of a captive breeding programme for this species (Carroll and Haring 1994). In 2005, the first aye-aye was born in captivity in the UK at Bristol Zoo Gardens in Bristol (Hosey *et al* 2009).

A study on the first captive breeding of this species reported the gestation period to be 158 days (Beattie *et al* 1992). Glander (1994) later reported an average gestation length for the species to be 167 days (range: 158 -172 days), this data was based on the information gained from three individuals housed at the DLC. The species gives birth to a single infant (Beattie *et al* 1992, Feistner and Ashbourne 1994, Glander 1994), with an average body weight of 109g (range = 90-136g) (Glander 1994). Glander (1994) found the weight of the offspring at birth relates to body weight of the mother, with the larger the adult female the larger the infant and vice versa. Studies have found the species to exhibit an extended period on parental care compared to other lemur species (Feistner and Ashbourne 1994, Krakauer 2005, Winn 1994a). The infant is found to be dependent on the mother milk for at least the first 14 weeks, moving on to solid food at around week 20, but still receiving food from the mother until a year old (Feistner and Ashbourne 1994).

This extended period of parental care is thought to be related to the specialist foraging behaviour that this species exhibits called 'percussive foraging' (Feistner and Ashbourne 1994, Krakauer 2005). This is a highly specialised foraging behaviour that requires fine motor-coordination and practice in order to perform it successfully (Feistner and Ashbourne 1994, Krakauer 2005).

A study on three captive aye-ayes found they reach sexual maturity at around 2.5 years of age (Winn 1994b). Unlike many other lemur species they are found to exhibit non-seasonal reproduction (Sterling 1994). Sterling (1994) carried out observations on wild aye-ayes over five months (October-February) and throughout this period witnessed mating and signs of oestrous. A study on two captive aye-ayes found they both were sexually active for 6-7 months of the year (Winn 1994b). The sexual cycles of these captive individuals commenced at slightly different times of year, one individual: November- May; second individual: January-July (Winn 1994). The species are thought to have a multi-male/multi-female mating system, with Sterling (1993) suggesting the males exhibit a polygyny approach to mating. Petter and Peyriéras (1970) cited by Mittermeier *et al* (2010) reported that mating in the species results in the birth of one single infant every two-three years.

Studies looking into the status of the captive population of this species are extremely limited (Riewald *et al* unpublished). A recent study on 177 mammal populations within EAZA institutes analysed the sustainability of the captive population of aye-ayes using five sustainability categories (1: Population less than 50; 2: Proportion of breeding individuals less than 25%; 3: Lambda less than one; 4: Less than 85% of the pedigree known; 5: Population has less than 30 founders). Results from this study revealed the aye-aye population failed three of these five categories: the population consists of less than 15 individuals, has low growth rates and a founder population is less than 30 individuals (Riewald *et al* unpublished). However, this study was a rapid analysis of the status on EAZA mammal populations; it suggests further analysis is required of any populations failing these sustainability categories.

2.2.3 Lorises in captivity

Lorises form part of the suborder Lorisiformes, this group of primates also includes the galagines and perodicticines (Cowlishaw and Dunbar 2000, Nekaris and Bearder 2007). Species within this suborder are considered to consist of some of

the most specialised of all primate species (Nekaris and Bearder 2007). The subfamily Lorisinae consist of two genera (*Loris and Nycticebus)* with species widely dispersed over Southern and Southeast Asia (Cowlishaw and Dunbar 2000, Nekaris and Bearder 2007). The taxonomy of these genera has both been under extensive review in recent years with the current number of species/subspecies still in debate (Nekaris and Bearder 2007). This was due to the nocturnal nature and cryptic features of this primate family resulting in many of its taxa being misclassified (Nekaris and Bearder 2007).

Bertram (1984) cited in Fitch-Snyder and Schulze (2000) reported the first slender loris to arrive at London Zoo occurred in 1832; however this individual died six days after arrival. In 1980, Ruhr University in Germany acquired a population of nine wild caught *Loris tardigradus nordicus* (Fitch-Snyder and Schulze 2000). This population successfully bred in captivity and became the founder population of a captive breeding programme for the species (Fitch-Snyder and Schulze 2000).

There have been a number of studies on the reproduction of the slender loris (Izard and Rasmussen 1985, Nekaris 2003, Radhakrishna and Singh 2003). *Loris l. lydekkerianus* is found to exhibit a multi-male, multi-female mating system in the wild (Radhakrishna and Singh 2003). The presence of a seasonal reproduction seemed to differ between species and findings from studies have had conflicting results (Izard and Rasmussen 1985, Nekaris 2003, Radhakrishna and Singh 2003). A study by Radhakrishna and Singh (2003) on a single wild *L. l. lydekkerianus* found the species to exhibit a seasonal reproduction whereas Izard and Rasmussen (1985) found no evidence of seasonal reproduction in a captive colony of ten *L. t. malabaricus*. Nekaris (2003) carried out a field study on the mating, birthing and parental behaviour of three slender loris taxa; *L. l. lydekkerianus; L. l. nordicus* and *L. t. tardigradus.* This field study observed males from all three taxa performing mating behaviours throughout the year (Nekaris 2003). Gestation periods vary between species ranging from 164-175 days and females slender lorises have been observed giving birth to either single or twin infants (Izard and Rasmussen 1985, Nekaris 2003, Radhakrishna and Singh 2003, Nekaris and Bearder 2007).

The Riewald *et al* (unpublished) study on the sustainability of EAZA's mammal population included the grey slender loris. Results from this research found similar findings to that of the aye-aye population with the population failing the same three sustainability categories (Riewald *et al* unpublished). This population was found to

consist of only 12 individuals dispersed over just four European institutions, have low growth rates and have a founder population of less than 30 founders (Riewald *et al* unpublished). Fitch-Snyder and Schulze (2000) report that the captive breeding of this species is challenging due to the small number of founders within the population.

A small amount of information on the history of pygmy slow loris (*Nycticebus pygmaeus*) in European institutions can be found in mainstream literature (Fitch-Snyder and Schulze 2000). The species is considered to be one of the least studied of all prosimian species (Fitch-Snyder and Ehrlich 2003, Fitch-Snyder and Jurke 2003). In 1986, approximately 37 individuals were imported to Sweden from the wild (Fitch-Snyder and Schulze 2000). Pairs of these individuals were later transported to North American zoos in 1987; these individuals are the founder population of all current North American zoo populations (Fitch-Snyder and Schulze 2000, Fitch-Snyder and Jurke 2003).

Studies focusing specifically on the reproduction parameters of pygmy slow lorises are very limited and have often been compared to its close relative the slow loris (*Nycticebus coucang*) (Fitch-Snyder and Jurke 2003). Reproduction studies of this species have mainly taken place in captivity (Jurke *et al* 1998, Fitch-Snyder and Jurke 2003). Sokolov *et al* (1993) and Feng *et al* (1994) cited by Fitch-Snyder and Jurke (2003) have found the species to exhibit seasonal reproduction with a distinct mating season occurring in July-September. This mating season also fits with a study by Fitch-Snyder and Jurke (2003) who found male pygmy slow loris exhibited higher levels of testosterone in July-August. A study looking in to the reproductive parameters of this species found the gestation period to be between 187-198 days (Jurke *et al* 1997). The species has a litter size of 1-2 offspring (Nekaris and Bearder 2007).

2.2.4 Galagos in captivity

Galagos (also known as bushbabies) are small nocturnal primates that inhabit a diverse range of habitats from near-desert to tropical rainforest throughout mainland Africa (Nekaris and Bearder, 2007). Galagos have cryptic morphological features, which has made taxonomic classification challenging (Nekaris and Bearder 2007. In recent years this primate group has been undergoing taxonomic revision. This has led to species numbers in this family increasing from six to 24 in the last ten years (Grubb *et al* 2003). Species have been identified through differences in hand, foot

and sexual organ morphology, vocalisations and behaviour as well as genetic research (Nekaris and Bearder 2007). The Galaginae family consists of five genera: *Galagoides*; *Galago*; *Euoticus*; *Sciurocherus* and *Otolemur* (Nekaris and Bearder 2007): Within the genus *Galago* there are currently four known species (Grubb *et al* 2003, Nekaris and Bearder 2007).

Studies on the captive breeding of galagos are limited (Lowther 1939, Eaglen and Simon 1980). Captive population studies on this primate family are not found in mainstream literature. The earliest record found of galagos breeding in captivity was published in 1939 (Lowther 1939). Lowther (1939) acquired a pair of southern lesser galago (*Galago moholi*) from Africa in 1937, this pair successfully mated and the female gave birth to twins two years later. This is thought to be the first recorded captive birth of this species in America (Lowther 1939).

A study on a wild population of Zanzibar lesser galagos (*Galagoides cocos*) found the species to have a seasonal reproduction with a peak number of births occurring at two times within a year (February/March and late August/October) (Harcourt 1986). The species was mainly found to give birth to singletons but twin births were also recorded (Harcourt 1986). Pullen *et al* (2000) found wild *Galago moholi* to also exhibit a twice yearly mating season occurring in May and late September to early October. Bearder (1969) cited in Harcourt and Bearder (1989) found wild populations of *Galago moholi* in South Africa regularly have twin births.

European captive populations of galagines consist of two species within the genus *Galago*: *G. moholi* and *G. sengalensis* (Senegal lesser galago) (Brandl 2011). However, both of these captive populations are currently undergoing taxonomic classification (Brandl 2011). Problems with the population include the unknown origin of all individuals within two large breeding populations (35+ individuals) currently housed in Moscow Zoo and Prague Zoo (Brandl 2011). There is also no living founder of the population of *G. moholi* (Brandl 2011). Once the pedigree, lineage and origin of all individuals within the captive populations have been determined a studbook and breeding pairs within European institutions will be set up for these species (Brandl 2011).

2.3 Unsuccessful species in captivity – tarsiers

Although still under debate, there are currently five recognised species of tarsier (Gursky 2007). These small nocturnal primates inhabit forested areas of Southeast Asia (Wright *et al* 1987, Gursky 2007). The morphological features of these primates have been found to vary greatly between species (Gursky 2007). Differences include body weight, limb proportion and absolute orbit and tooth size (Gursky 2007). The smallest of the tarsier species is the pygmy tarsier (*Tarsius pumilus)* weighing approximately 58g (Wright *et al* 1987, Gursky 2007). This species have only been found in mountainous areas of Sulawesi and are considered to be one of the 25 most endangered primates in the world (Wright *et al* 1987, Mittermieier *et al* 2012).

Tarsiers have a highly specialised diet (Wright, 2003); they are obligate predators and are considered to be the only primate to be exclusively faunivorious (Bearder 1987, Roberts and Kohn 1993, Colishaw and Dunbar 2000, Fitch-Snyder 2003, Gursky 2007). Their diet consists of 90% arthropods and 10% vertebrates (Colishaw and Dunbar 2000).

A study on the gestation period of a western tarsier found the species to have a long gestation period (178 days) for their small body size (Izard *et al* 1985). At birth the tarsier offspring weighs approximately one quarter of an adults weight, with the mother giving birth to a single infant (Izard *et al* 1985, Haring and Wright 1989). A five year study on the growth and development of western tarsier in captivity found them to exhibit a slow fatal growth rate and slow postnatal growth rate to maturity (Roberts 1994). The study suggests there is a relationship between these slow growth rates and the species highly specialised diet (Roberts 1994). As obligate predators (Bearder 1987), this species require highly specialised foraging skills, offspring are born with a large neonatal brain size, which is thought to allow them to develop behavioural and neuromuscular coordination quickly (Roberts 1994). At around 30 days old individuals have been found to make their first attempts to predate on live prey (Roberts 1994).

Despite many attempts to keep tarsiers in captivity, zoos have been unable to sustain captive populations (Wright *et al* 1987, Wright *et al* 1989, Fitch-Snyder 2003). The philppine tarsier (*Tarsius syrichta)* has been found to reproduce poorly in captivity and offspring are found to have a low survival rate (Wright *et al* 1987,

Haring and Wright 1989). A study by Roberts (1994) on nine western tarsier (*Tarsius bancanus)* offspring found four of these individuals died either at or shortly after birth, and a further individual died after 19 days. Live births of the western tarsier and philippine tarsiers in captivity is considered a rare event as the mother often miscarries or dies before giving birth (Robert and Kohn 1993). A hand-full of successful live births have been found to result in a live infant reaching weaning age (Wright *et al* 1987, Roberts 1994; Hirota *et al* 2011). Sadly, many infants die before this time from injury or maternal neglect (Haring and Wright 1989, Roberts 1994, Hirota *et al* 2011).

Life history factors and their highly specialist diet have been suggested as possible causes for these species failing to survive in captivity (Wright *et al* 1989, Roberts and Kohn 1993, Fitch-Snyder 2003). Wright *et al* (1989) suggest for these species to survive in the captive environment they need to perform the same foraging behaviours as they exhibit in the wild. The habitat requirements and social behaviours have been found to vary between tarsier species (Wright *et al* 1987, Wright *et al* 1989). Wright *et al* (1987) found differences in the activity level, foraging behaviours and preferences in sleeping and resting sites of captive philippine tarsiers and western tarsiers. Wright *et al* (1989) stresses that these differences need to be taken into account when designing the captive environment and conducting husbandry practices for these species. In order to successfully keep western tarsiers in captivity Roberts and Kohn (1993) suggests their diet, social requirements and enclosure space and substrate all need to be carefully managed.

Part 1

Chapter Three

3.0 Methodology

3.1 Study Subjects

In this study I looked at the following European captive populations of nocturnal prosimians: fat-tailed dwarf lemur (*Cheirogaleus medius*), Goodman's mouse lemur (*Microcebus lehilahytsar*), grey mouse lemur (*Microcebus murinus*), grey slender loris (*Loris lydekkerianus*), and pygmy slow loris (*Nycticebus pygmaeus*). I also included the international captive population of aye-ayes (*Daubentonia madagascariensis*). Due to the small captive population size the aye-aye studbook is managed on an international level.

Captive breeding programmes are recommended for these populations by the EAZA Prosimian TAG (Table 3). The species chosen are currently managed under the EAZA captive breeding programme for threatened species at either the European Endangered Species programme (EEPs) or European Studbooks (ESBs) level (Table 1). Each chosen population has a studbook containing both current and historical population data.

3.2 Study site

Individuals within these populations are housed at a number of EAZA institutions throughout Europe. As previously mentioned in Chapter Two these nocturnal prosimians are generally kept in nocturnal houses with a reverse light cycle to simulate night-time during daylight hours. As members of EAZA each institution is required to comply with specific codes and standards set by the association (EAZA 2012). These include minimum standards of accommodation and care for animals in zoos and aquaria, codes of ethics and the IUCN guidelines for the management of ex-situ populations for conservation (EAZA 2012).

3.3 Ethical Considerations

This research does not involve any contact with animals, changes to animal enclosures or feeding regimes and therefore will not cause any foreseen distress, pain or suffering to animals that would lead to ethical concerns (I.S.A.E 2012).

As this study is part of a MSc by Research thesis, the submission of a University Research Ethics Committee (UREC) E2U form was not a requirement (Wilson, M. Pers comm.). A University Faculty Ethics HSS.E2 form (Application for ethics approval for a research project involving human participants) was also not required as no human participants were involved and no personal information was requested. All data collected during this part of the study related to the captive population of primate species.

3.4 Materials

The studbook data for each study subject were required for this study. These studbooks contain both historical and current data on each captive population. These data are maintained as an electronic file by the studbook keeper. This type of data was used in previous published studies to analyse captive populations (Ange-Van Heugten *et al* 2010, Glatston 2001, Reid *et al* 2012, Kaumanns *et al* 2008).

To access the electronic studbook data files the following zoological computer software programme was required: Single Population Animal Records Keeping Software (SPARKS). This computer software was developed by the International Species Information system (Bingaman Lackey 2010). It is a DOS-based computer programme that allows studbook keepers to maintain and produce a studbook on a single species that is held at a number of institutions (Bingaman Lackey 2010). The version of this computer software programme used for the study was SPARKS Version 1.54. Access to this computer software was kindly provided by Bristol Zoo Gardens, Bristol, England.

3.5 Data Collection

In order to obtain the electronic SPARKS files for the study subjects the individual studbook keepers for each captive population were contacted. These files were then

sent electronically to the researcher. Data from these files were then downloaded on the SPARKS computer software package.

Using this downloaded studbook data the following historical and living population data for each individual within each captive population were collected and recorded onto a specifically designed Microsoft Excel spreadsheet. This type of studbook data was used in similar studies to analyse captive populations of primates (Ange-Van Heugten *et al* 2010, Kaumanns *et al* 2008).

- Studbook number
- Birth date
- Birth origin (wild or captive born)
- Start date in captivity
- Sex of individual
- Parents (Studbook numbers)
- Date of death
- Cause of death (if known)
- Location at birth (zoological institution)
- Current location (zoological institution)

The studbook data were collected from 1st January 1990. This was the year EEPs were first set up (Kaumanns *et al* 2008). This start date was also used by previous published studies on captive primate populations (Ange-Van Heugten *et al* 2010, Kaumanns *et al* 2008). However, the population data from one study subject (Goodman's mouse lemur) was collected from the year 1997; this was when the first birth was recorded for this population.

The end date of the recording period varied depending on the most current studbook available. Population data was recorded for each population over the following periods of time:

Aye-aye (*D. madagascariensis*) - 1st January 1990 - 31st December 2011.

Fat-tailed dwarf lemur (*C. medius*), - 1st January 1990 - 31st December 2010.

Goodman's mouse lemur (*M. lehilahytsar*) - 1st January 1997 - 31st December 2011

Grey mouse lemur (*M. murinus*) - 1st January 1990 - 31st December 2010.

Grey slender loris (*L. lydekkerianus*) - 1st January 1990 - 31st December 2010.

Pygmy slow loris (*N. pygmaeus*) - 1st January 1990 - 31st December 2010.

3.6 Data Analysis

All population data collected were analysed to provide demographic data on each population (historical and living). The following information was calculated using the collected data: age, total population size each year; total births/deaths each year; total infant deaths (individual under 1 year of age on date of death) each year; sex ratio and age structure of the living population; percentage of total increase/decrease in population size, percentage of infant deaths and the total number of EAZA institutions currently holding the species. To measure the demographic health of ex-situ breeding programmes effectively Baker (2007) suggests using the number of animals and age structure of a captive population.

Birth, mortality and natural increase rates of each population were calculated to allow statistical tests to be carried out. The following formulas were used (Shryock *et al* 1976):

Number of births in a year/population x 1,000 = crude birth rate
Number of deaths in a year/population x 1,000 = crude death rate
Number of infant deaths in a year/number of births in a year x 1,000 = Infant mortality rate
Births in a year - deaths in a year/population x 1,000 = crude rate of natural increase

3.7 Statistical Analysis

The computer software package IBM SPSS Statistic Version 19.0 was used to carry out statistical tests on the collected population data.

The paired t-test was used to determine if there was a difference between annual birth and death rates for each species (Dytham 2003, Hawkins 2009). This statistical test was carried out on six study subjects (section 3.1). A paired t-test was considered appropriate because the scale data being analysed had a normal distribution and contained two related variables (birth and death rate) (Dytham 2003, Hawkins 2009).

The average annual Infant mortality rates for each species were statistically analysed to determine if there is a difference between the captive populations. The Kruskal-Wallis statistical test was used for this analysis as this test looks for differences between two or more unrelated samples (Dytham 2003, Hawkins 2009). This test was conducted on six captive populations. Kaumanns *et al* (2008) used this method to see if there were differences in the infant mortality rates of different taxonomic groups of captive primate populations.

The age and sex composition of the living populations of the study subjects was also statistically analysed. The chi-square test was used to find out if there was a difference between the age groups of males and females within each living population. The age groups used for this test were: 0-4 years; 5-9 years; 10-14 years; 15-19 years; 20-24 years; 25-29 years; 30-34 years. This statistical test was carried out on six living populations. The chi-square test was considered appropriate as it tests for differences between categorical data (Dytham 2003, Hawkins 2009).

Part 1

Chapter Four
4.0 Results

4.1 International captive population of aye-aye

4.1.1 Population development

The size of the International captive population of aye-aye remained static between the years 1991 and 1994, with a total of 8 individuals occurring in the population during this time (Figure 1). After this date the population shows a steady increase. The population size at the end of the study period (1st January 2012) was 16 individuals (Table 4). Over the whole study period the population size saw an increase of 433.3% (Table 5). The population's average annual rate of natural increase calculated from the whole period of analysis was 2.85 (Table 4).

There were no births in the population within the first two years of the study period (1990 and 1991) (Figure 2). There were no births or deaths in the population in the years 1991 and 2000. The largest amount of births in one year occurred in 2003 (3 individuals were born); the largest number of deaths occurred the following year and consisted of the same number of individuals. Eight of the years within the study period saw the equal number of births to deaths occurring. Within this period the total number of births equalled 26, and the total number of deaths equalled 22. Average annual birth rate of the population was 92.04 and average annual death rate of the population was 89.19 (Table 4).

The chi-square test was used to find out if there was a significant difference between the age groups of males and females within the living population (Dytham 2003, Hawkins 2009). At a 0.05% significance level the test found no significant difference ($P = 0.163$) (Appendix 3a).

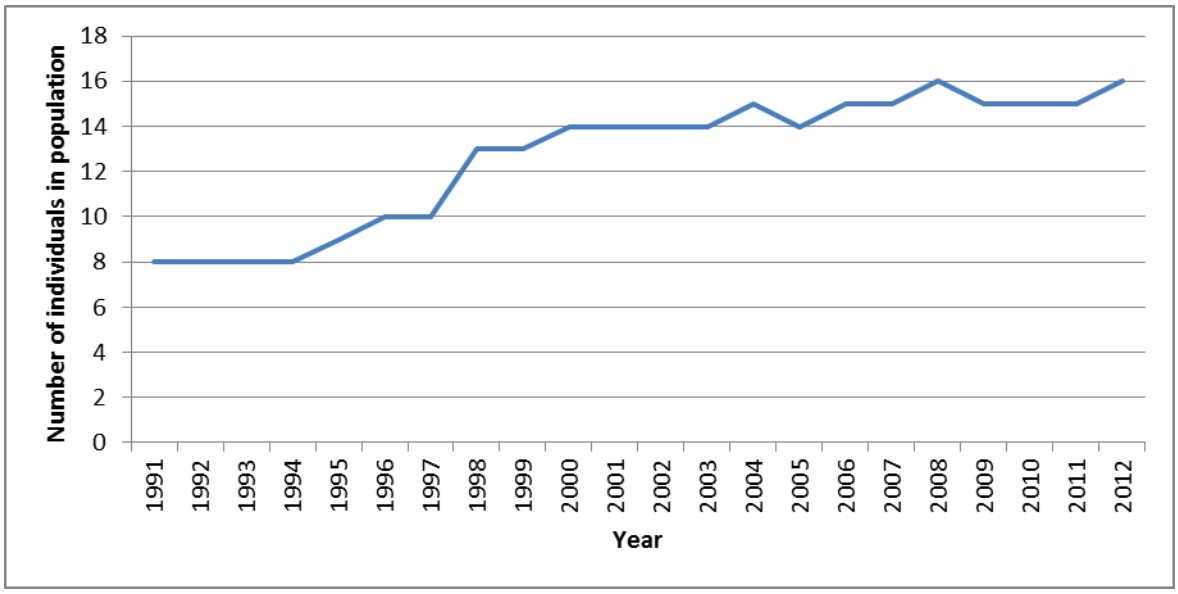

Figure 1: Line graph displaying the population development of the international captive population of aye-aye between the years 1990 – 2012 (at 1st January). This graph indicates a gradual increase in population size from 1994 to 2012.

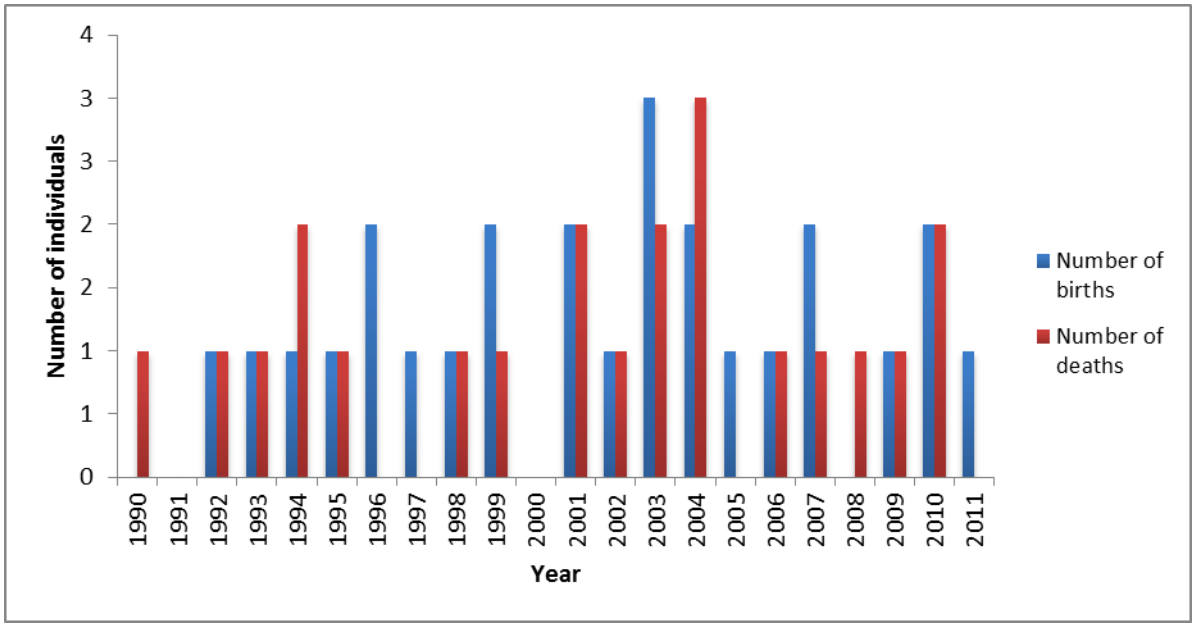

Figure 2: Bar chart displaying the number of births and deaths within the international captive population of aye-aye between the years 1990 – 2011.The chart highlights that the highest number of total births in one year occurred in 2003. The highest number of total deaths in one year occurred in 2004.

4.1.2 Sex composition and age structure

At the end of the period of analysis the aye-aye population consisted of a total of eight males and eight females (Table 4). The age range of the population consisted of: two males aged between 0-4 years old; two females aged between 5-9 years old; two males and three females aged between 10-14 year olds; two males aged between 15-19 years old; one male and one female aged 20-24 years old; and two females aged between 30-34 years old (figure 3).

The chi-square test was used to find out if there was a significant difference between the age groups of males and females within the living population (Dytham 2003, Hawkins 2009). At a 0.05% significance level the test found no significant (P = 0.163 (Appendix 3a).

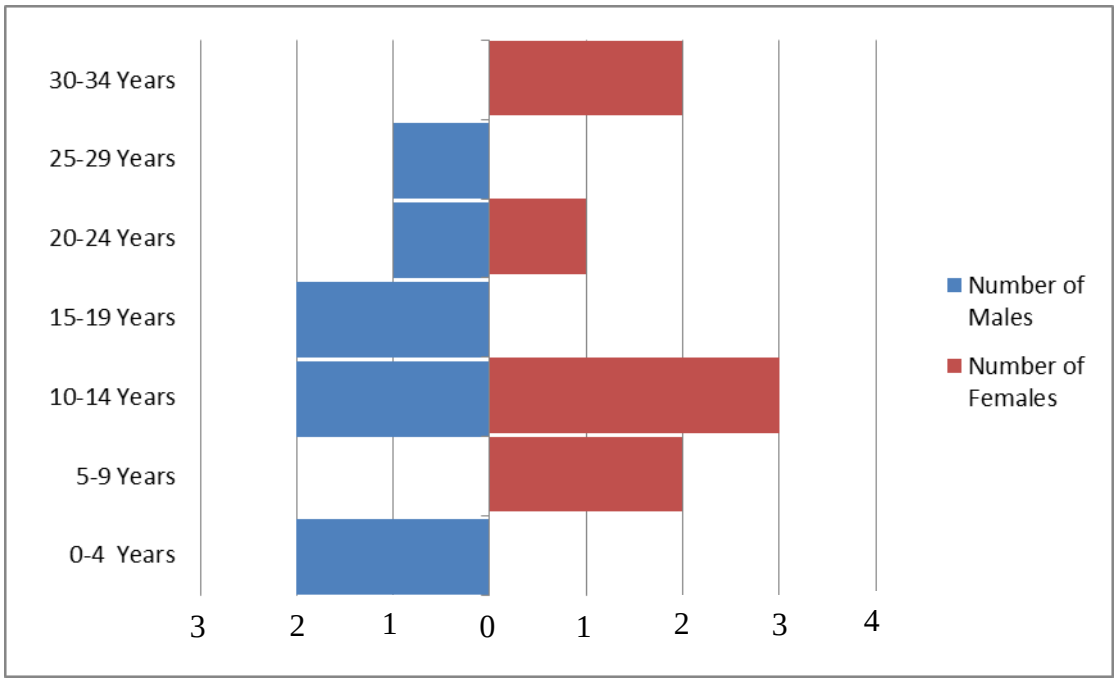

Figure 3: Age pyramid displaying the sex composition and age structure of the international living population of aye-ayes in 2012 (at 1st January). This graph highlights that there are no females aged between 0-4 years within the population.

4.2 European captive population of fat-tailed dwarf lemur

4.2.1 Population development

The European captive population of fat-tailed dwarf lemur increased from the years 1990 to 1995 (Figure 4). The population was at its largest size in 1995 (58 individuals), after this year the population gradually decreased in size. The population on 1st January 2011 consisted of 21 individuals (Table 4). The population size saw a decrease of 48.8% over the whole study period (Table 4, 5).The population's average annual rate of natural increase was -4.51 (Table 4).

This population experienced its peak number of total births in 1993, with 14 individuals born over this time period (Figure 5). The highest number of total deaths in one year occurred in 1995, with a total of 10 individuals dying over this time period. Four separate years within this study period (1997, 2005, 2009 and 2010) witnessed no births within the population. Within the study period the total number of births equalled 80 and the total number of deaths equalled 78. The average annual birth rate of the population was 87.47 and average annual death rate of the population was 91.99 (Table 4).

The paired t-test was used to investigate whether there was a difference between annual birth and death rates (Dytham 2003, Hawkins 2009). At a 0.05% significance level the test found no significant difference (t_{20} = 0.223, P = 0.826) (Appendix 1b).

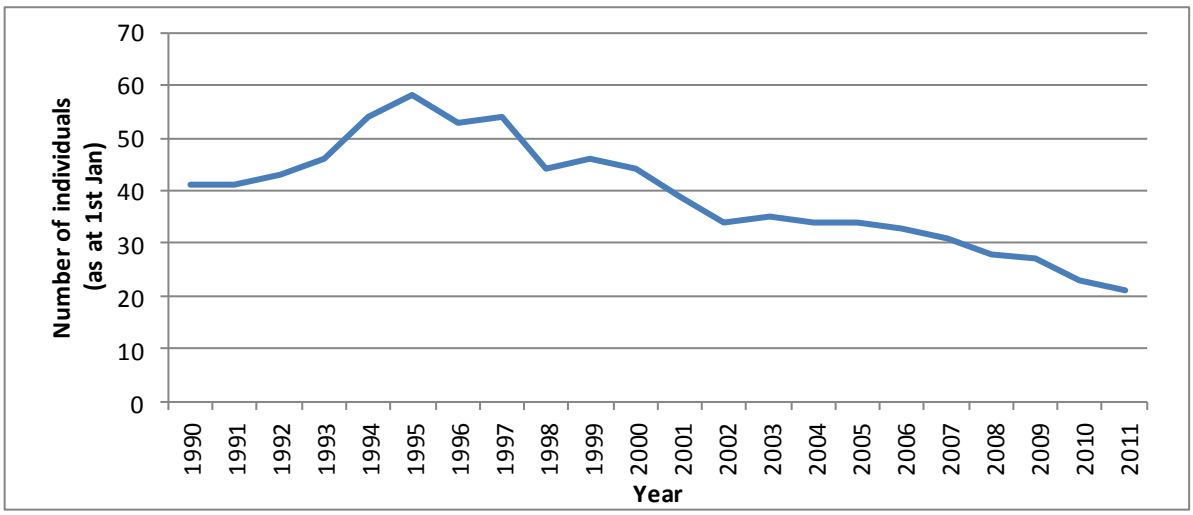

Figure 4: Line graph displaying the population development of the European captive population of fat-tailed dwarf lemur between the years 1990 – 2011 (at 1st January). This graph demonstrates the population has decreased in size since 1995.

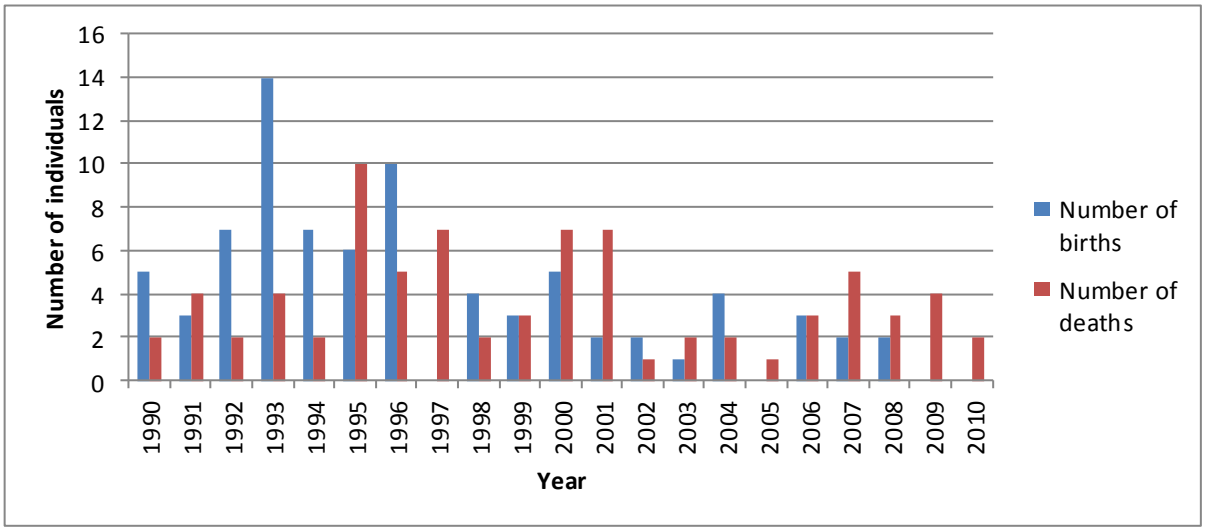

Figure 5: Bar chart displaying the number of births and deaths within the European captive population of fat-tailed dwarf lemur between the years 1990 – 2010. This chart highlights the highest number of total births in one year occurred in 1993.

4.2.2 Sex composition and age structure

At the end of the period of analysis the fat-tailed dwarf lemur population consisted of a total of 10 male and 11 females (Table 4). The age structure of the population consisted of: two males and one females aged between 0-4 years old; two males and four females aged between 5-9 years old; three males and four females aged between 10-14 year olds; one male and two female aged between 15-19 years old; and one male aged 20-24 years old (Figure 6).

The chi-square test was used to find out if there was a significant difference between the age groups of males and females within the living population (Dytham 2003, Hawkins 2009). At a 0.05% significance level the test found no significant difference (P =0.681) (Appendix 3b).

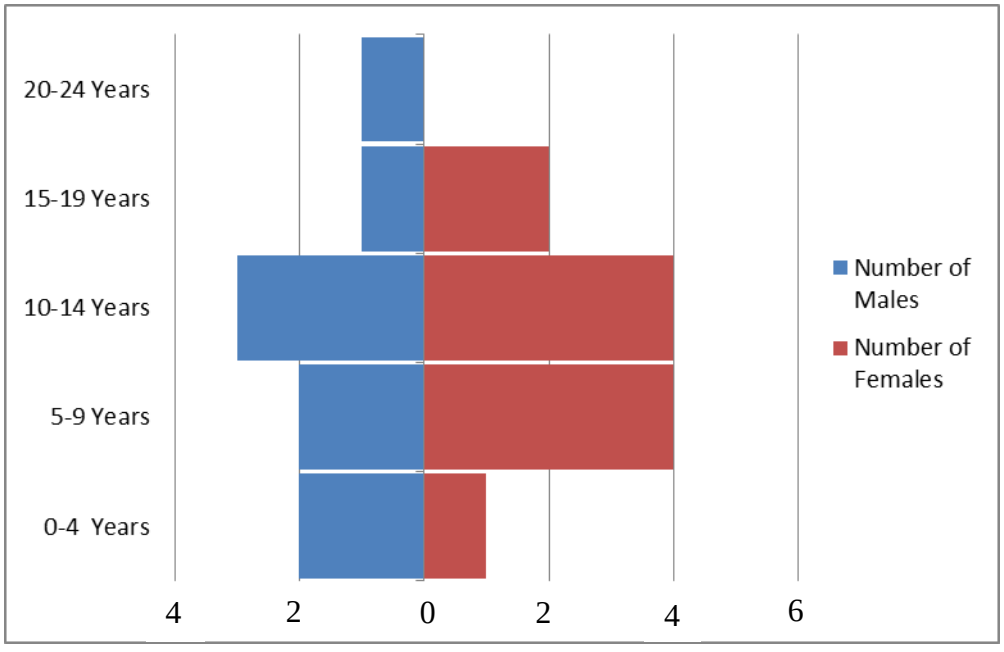

Figure 6: Age pyramid displaying the sex composition and age structure of the European living population of fat-tailed dwarf lemurs in 2011 (at 1st January). Population also includes one male of unknown age. This graph shows the number of females in three separate age classes outweigh the number of males.

4.3 European captive population of Goodman's mouse lemur

4.3.1 Population development

The European captive population of Goodman's mouse lemur showed a small increase between the years 1997 and 2005 (Figure 7). The population then experienced a rapid increase in size from 2005 to 2011. A slight decrease in the population was seen in 2012. The population size at 1st January 2012 was 85 individuals (Table 4). Over the whole study period the population size saw an increase of 2025% (Table 5). The population's average annual rate of natural increase was 209.90 (Table 4).

No deaths were reported in this population from the years 1997 to 2000 (Figure 8). In 1998 there were no births or deaths recorded within the population. Between the years 2006 to 2009 the number of births greatly increased, with the greatest number of births in one year occurring in 2009 (28 individuals). No births occurred in 2011. Within the study period the total number of births equalled 85 and the total number of deaths equalled 11. The average annual birth rate of the population was 234.25 and the average annual death rate of the population was 24.35 (Table 4).

The paired t-test was used to investigate whether there was a difference between annual birth and death rates (Dytham 2003, Hawkins 2009). At a 0.05% significance level the test found there was a significant difference between birth and death rates (t_{14} = 4.096, P = 0.001) (Appendix 1c).

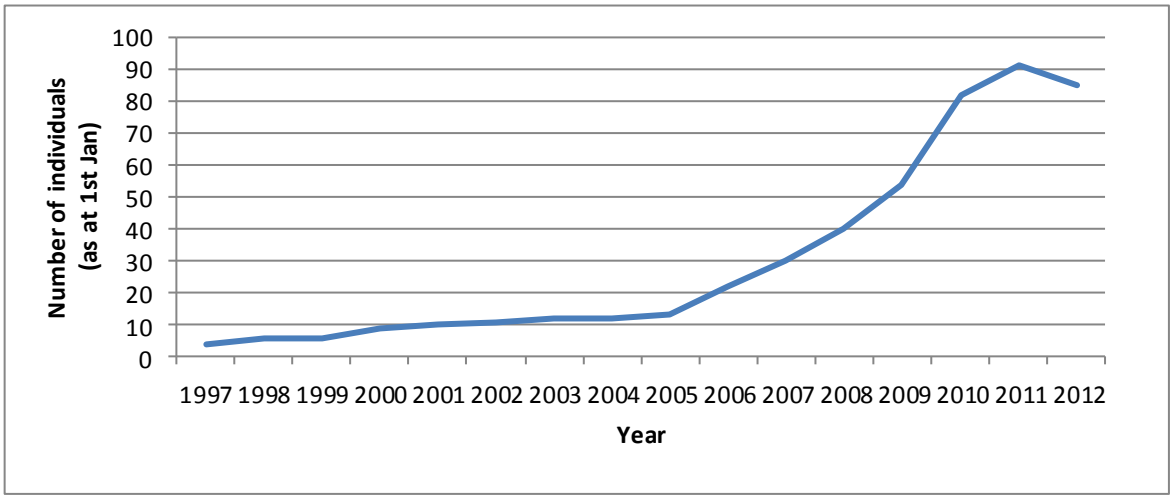

Figure 7: Line graph displaying the population development of the European captive population of Goodman's mouse lemur between the years 1997 – 2012 (at 1st January). This line graph highlights the rapid increase in population size since 2005.

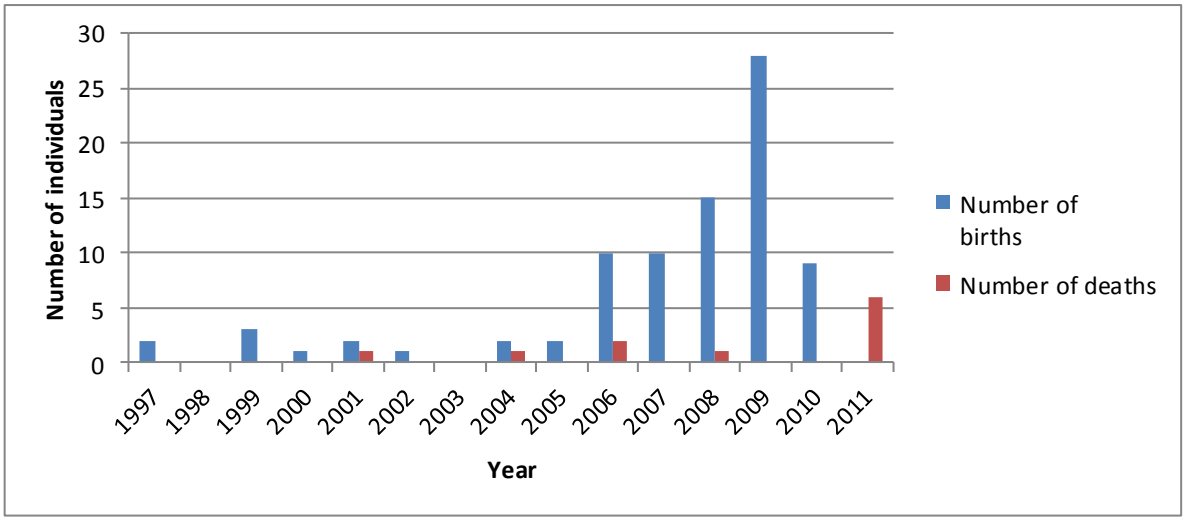

Figure 8: Bar chart displaying the number of births and deaths within the European captive population of Goodman's mouse lemur between the years 1997 – 2011. This chart shows the highest number of births in one year took place in 2009.

4.3.3 Sex composition and age structure

At the end of the study period the Goodman's mouse lemur population consisted of a total of 46 male and 39 females (Table 4). The age structure of the population consisted of: 35 males and 25 females aged between 0-4 years old; seven males and 11 females aged between 5-9 years old; and four males and three females aged between 10-14 year olds (Figure 9).

The chi-square test was used to find out if there was a significant difference between the age groups of males and females within the living population (Dytham 2003, Hawkins 2009). At a 0.05% significance level the test found no significant difference (P =0.344) (Appendix 3c).

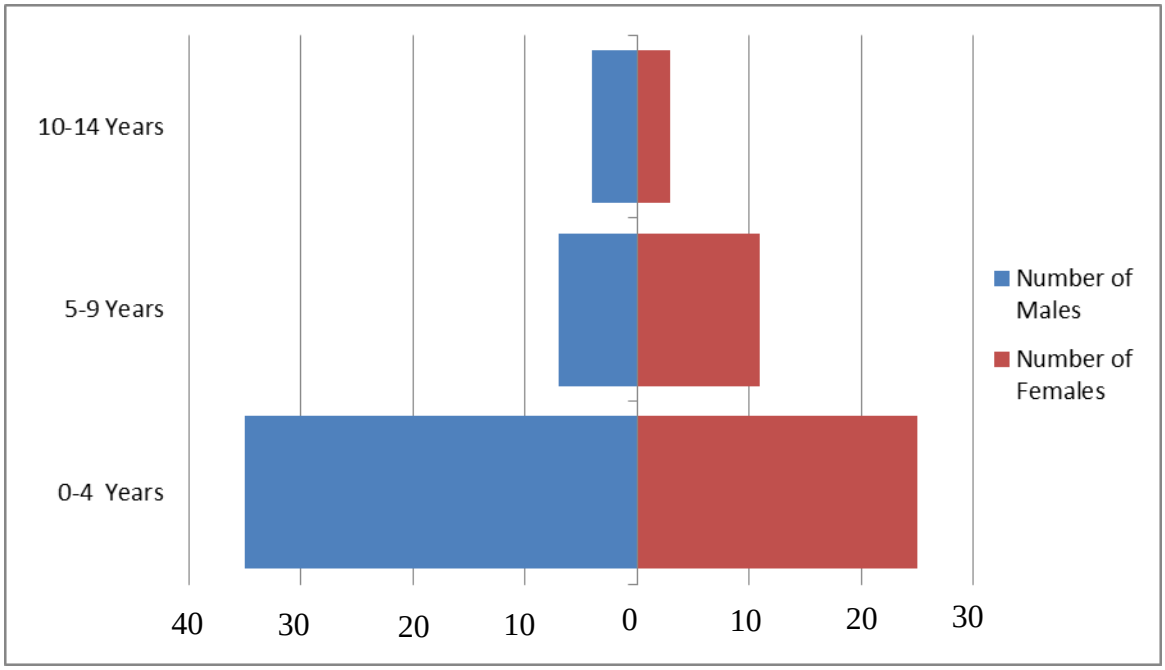

Figure 9: Age pyramid displaying the sex composition and age structure of the European living population of Goodman's mouse lemurs in 2012 (at 1st January). This graph indicates that the youngest age class has of the highest number of males and females.

4.4 European captive population of grey mouse lemur

4.4.1 Population development

The European captive population of grey mouse lemur increased between 1990 and 1995 (Figure 10). The population's reaching its peak size in 1995 (total of 346 individuals). Over the following ten-year period (1996- 2006) the population shows a declining population trend. In 2007 the population started to slowly increase. On the 1st January 2012 the total recorded European population consisted of 217 individuals (Table 4). The population size saw an increase of 33.9% over the study period (Table 5). The population's average annual rate of natural increase was 25.05 (Table 4).

The total number of reported births and deaths each year within this population is shown in Figure 11. Through presenting this data visually, it is possible to identify three distinct periods of time where there is a pattern of total number of births to deaths. First period: 1990-1994 the number of births within the population is much greater than the number of deaths; second period: 1995-2004 (with the exception of the years 1998 and 1999) the numbers of deaths within the population were much greater than the number of births; and the third period: 2005-2010 the number of births per year was greater than the number of deaths. Within the study period the total number of births equalled 879 and the total number of deaths equalled 772. The average annual birth rate of the population was 176.94 and the average annual death rate of the population was 151.89 (Table 4).

The paired t-test was used to investigate whether there was a difference between annual birth and death rates (Dytham 2003, Hawkins 2009). At a 0.05% significance level the test found no significant difference (t_{21} = 1.435, P = 0.166) (Appendix 1d).

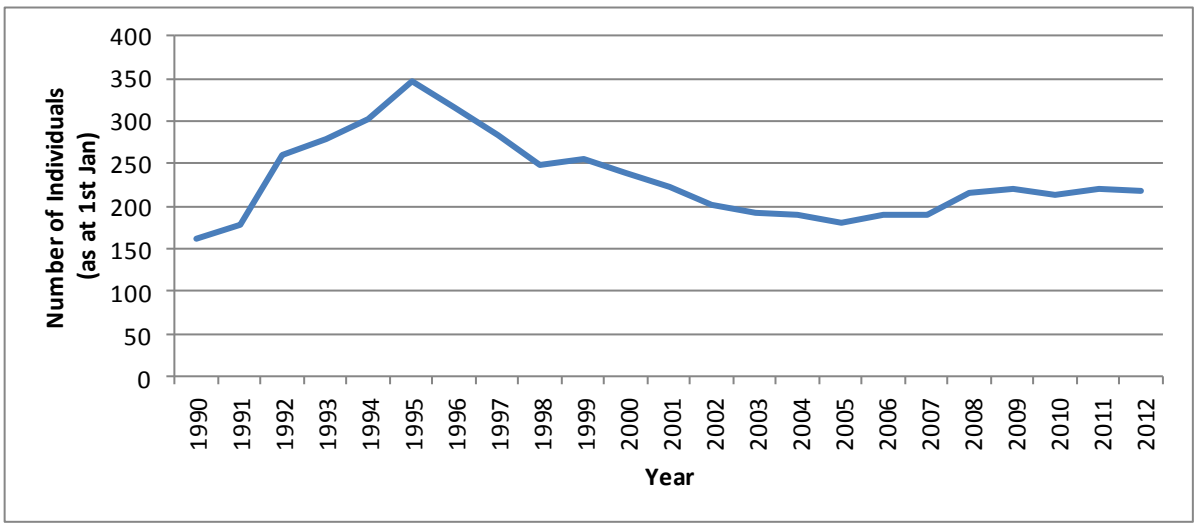

Figure 10: Line graph displaying the population development of the European captive population of grey mouse lemur between the years 1990 – 2012 (at 1st January). This graph shows the population size peaked in 1995.

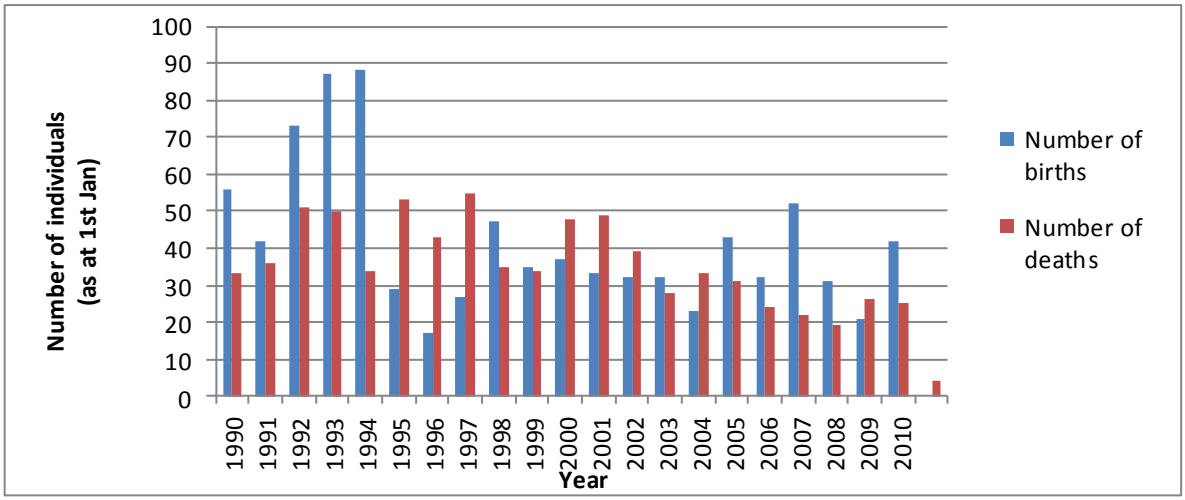

Figure 11: Bar chart displaying the total number of births and deaths each year in the European captive population of grey mouse lemur between the years 1990 – 2011. This chart highlights that the highest number of births occurred in 1994.

4.4.2 Sex composition and age structure

At the 1st January 2012 the grey mouse lemur population consisted of 103 male, 100 females and 14 individuals of unknown sex (Table 4). The age structure of the population consisted of: 64 males and 48 females aged between 0-4 years old; 34 males and 41 females aged between 5-9 years old; four males and nine females aged between 10-14 year olds; and one female aged between 15-19 years old (Figure 12).

The chi-square test was used to find out if there was a significant difference between the age groups of males and females in the living population (Dytham 2003, Hawkins 2009). At a 0.05% significance level the test found no significant difference (P =0.175) (Appendix 3d).

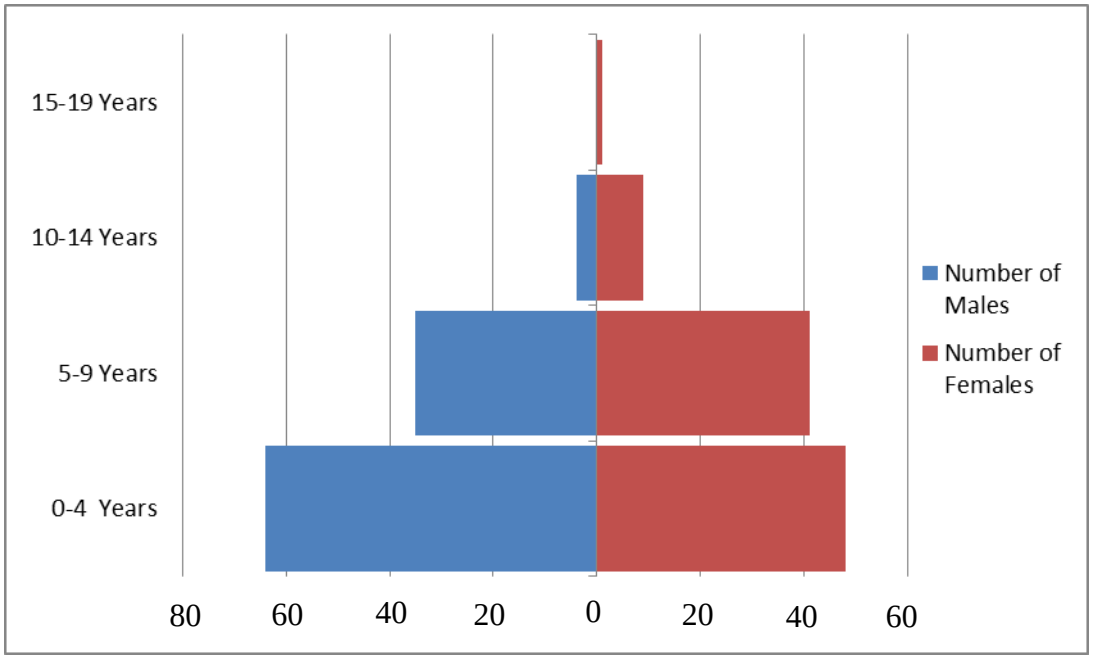

Figure 12: Age pyramid displaying the sex composition and age structure of the European living population of grey mouse lemurs in 2012 (at 1st January). The graph shows the age class 0-4 years consisted of the most males and females.

4.5 European captive population of grey slender loris

4.5.1 Population development

The grey slender loris population increased from the years 1993 to 1996, with the population reaching its peak number of individuals in 1996 (65 individuals) (Figure 13). Between the years 1997 to 2009 the population experienced a steep decline, with the total number of individuals decreasing to 20 individuals. The population size at the end of the study period was 23 individuals (Table 4). Over the study period the population size saw a decrease of 60.3% (Table 5). The population's average annual rate of natural increase was -36.71 (Table 4).

The population saw a greater number of deaths compared to births in the years 1997 to 2007 (Figure 14). The highest number of deaths was recorded in 1994, with a total of 15 deaths occurring this year. The greatest number of births took place in 1994 and consisted of 18 individuals. Within the study period the total number of births equalled 143 and the total number of deaths equalled 174. The average annual birth rate of the population was 136.96 and the average annual death rate of the population was 173.67 (Table 4).

The paired t-test was used to investigate whether there was a difference between annual birth and death rates (Dytham 2003, Hawkins 2009). At a 0.05% significance level the test found no significant difference (t_{21} = -2.069, P = 0.052) (Appendix 1e).

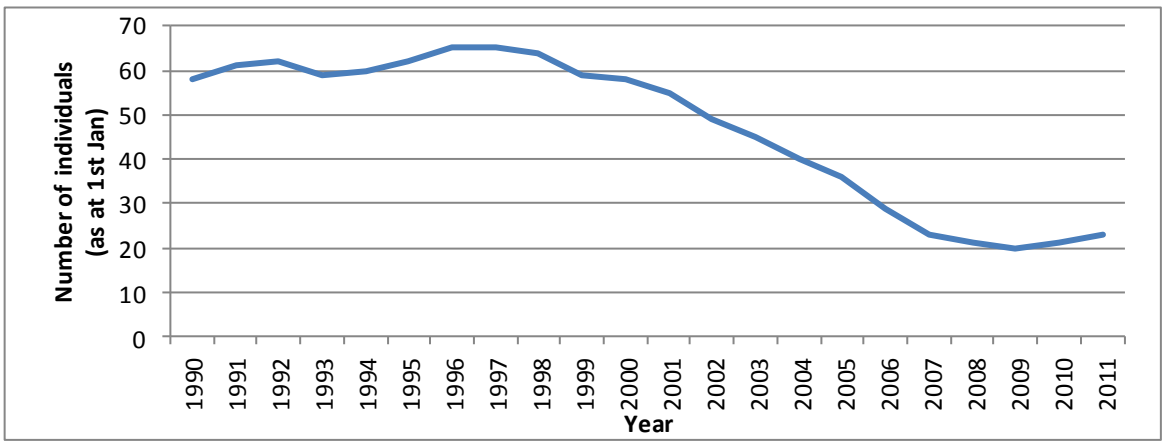

Figure 13: Line graph displaying the population development of the European captive population of grey slender loris between the years 1990 – 2011 (at 1st January). This line chart highlights the large decrease in total population size between 1997 and 2009.

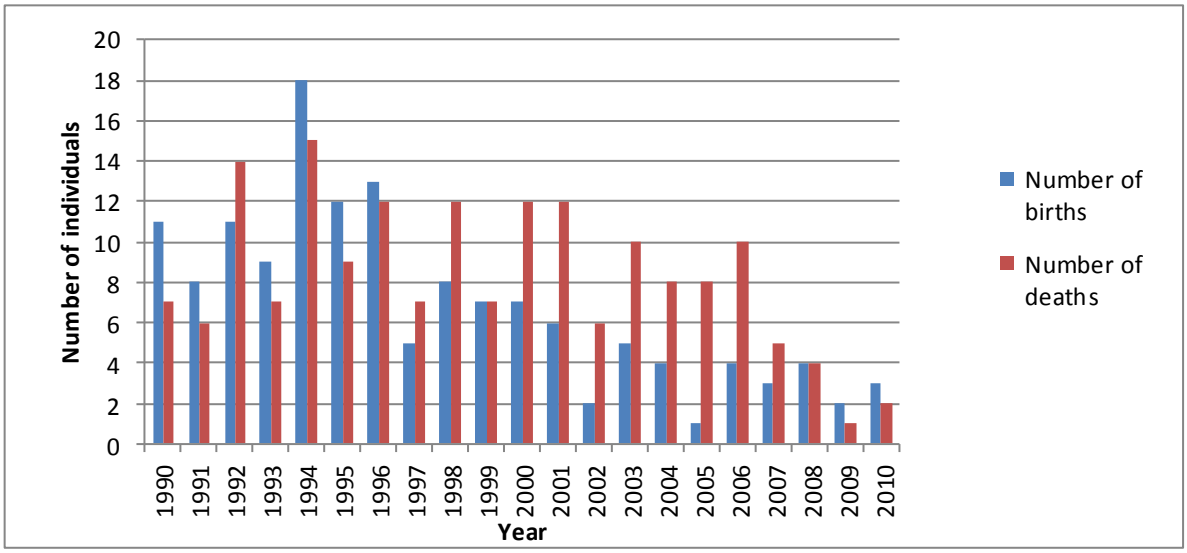

Figure 14: Bar chart displaying the number of births and deaths within the European captive population of grey slender loris between the years 1990 – 2010. This chart shows the highest number of total births and deaths occurred in 1994.

4.5.2 Sex composition and age structure

At the end of the study period the grey slender loris population consisted of a total of 10 males, 10 females and three individuals of unknown sex (Table 4). The age structure of the population consisted of: three males and six females aged between 0-4 years old; five males and two females aged between 5-9 years old; and two males and two females aged between 10-14 year olds (Figure 15).

The chi-square test was used to find out if there was a significant difference between the age groups of males and females within the living population (Dytham 2003, Hawkins 2009). At a 0.05% significance level the test found no significant difference (P =0.319) (Appendix 3e).

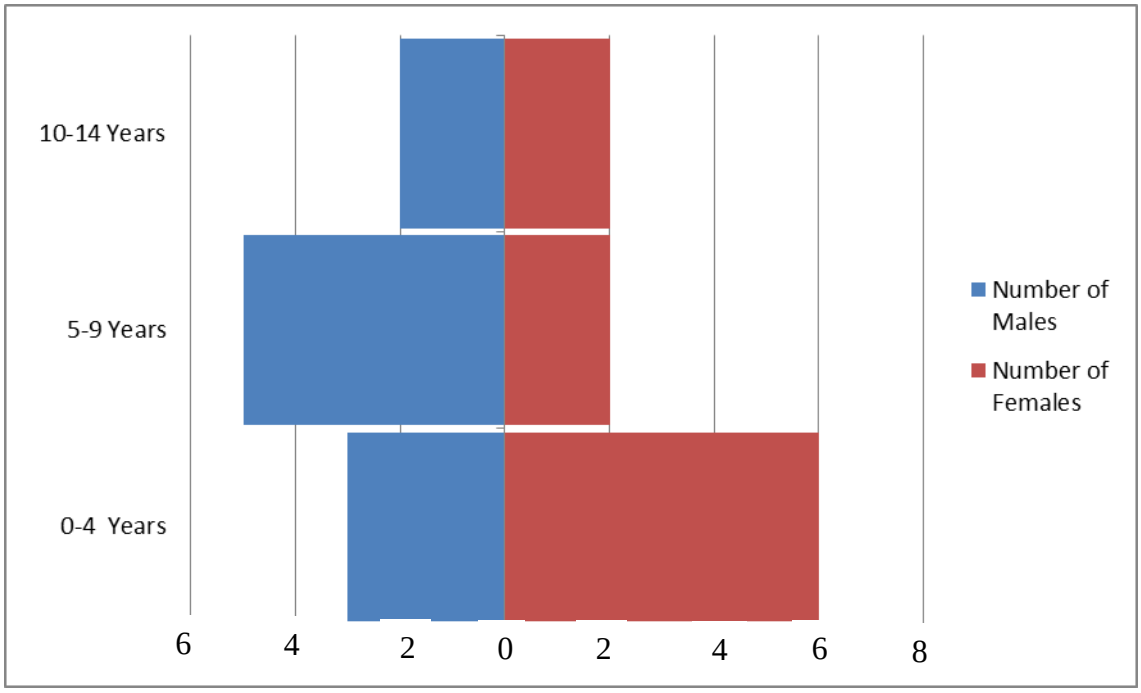

Figure 15: Age pyramid displaying the sex composition and age structure of the European living population of grey slender loris in 2011 (at 1st January). This graph shows the highest numbers of females within the population are between 0-4 years old. The highest numbers of males occurring in one age class are aged between 5-9 years old.

4.6 European captive population of pygmy slow loris

4.6.1 Population development

The pygmy slow loris population has seen a slow and intermittent increase in size through the period from 1991 to 2011 (Figure 16). The starting population size equalled 71 individuals with a total end population size of 90 individuals (Table 4, Figure 16).The peak population size occurred in 2009 with a total population size of 96. Over the whole study period the population size saw an increase of 26.8% (Table 5). The population's average annual rate of natural increase was -15.88 (Table 4).

In 1990 this population experienced a very low number of births compared to deaths (one birth and 13 deaths) (Figure 17). The number of births in the population saw a large increase in 1991 with 10 individuals being born. The largest number of births a year within the study period took pace in 2008 with 19 individuals being born that year. This was followed by the highest number of deaths in 2009 (21 deaths). Total number of births over the study period equalled 215 and the total number of deaths equalled 243. Through the whole study period the average annual birth rate of the population was 122.76 and the average annual death rate of the population was 138.64 (Table 4).

The paired t-test was used to investigate whether there was a difference between annual birth and death rates (Dytham 2003, Hawkins 2009). At a 0.05% significance level the test found no significant difference (t_{20} = -1.350, P = 0.192) (Appendix 1f).

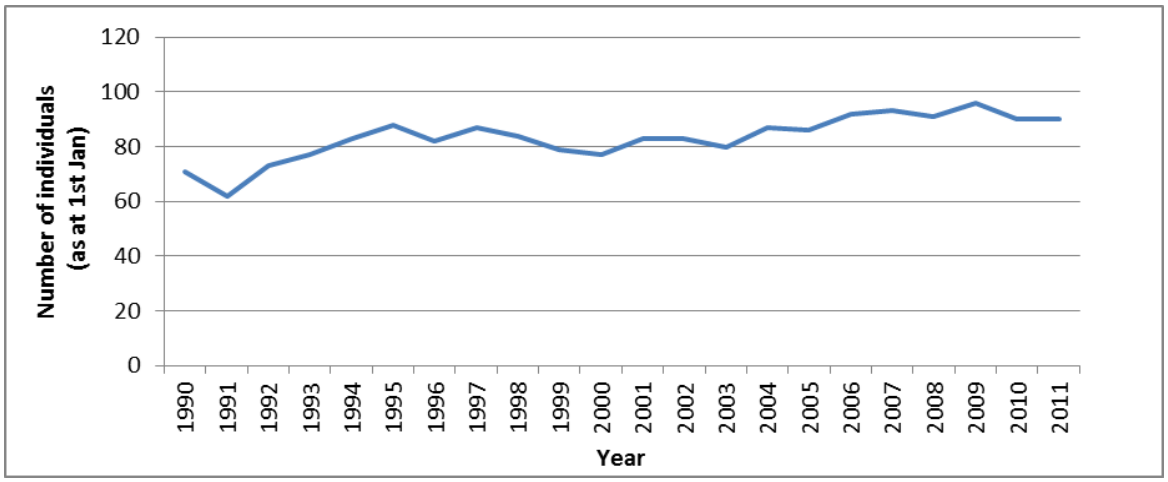

Figure 16: Line graph displaying the population development of the European captive population of pygmy slow loris between the years 1990 – 2011 (at 1st January). This line graph demonstrates that the population has gradually increased in size since 1990.

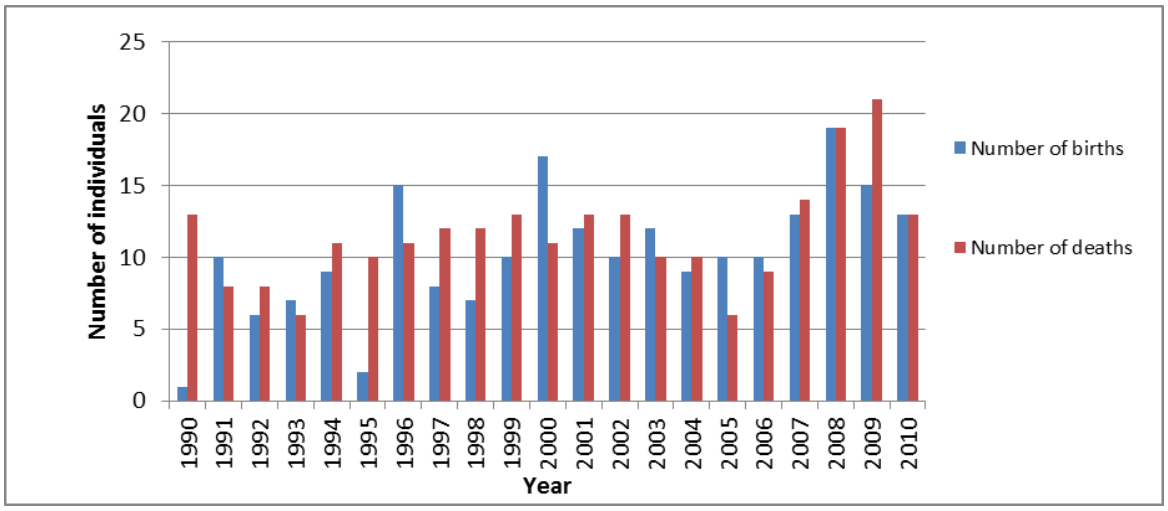

Figure 17: Bar chart displaying the number of births and deaths within the European captive population of pygmy slow loris between the years 1990 – 2010. This chart highlights the highest total number of deaths within one year occurred in 2009.

4.6.3 Sex composition and age structure

At the end of the study period the pygmy slow loris population consisted of a total of 51 male and 39 females (Table 4). The age structure of the population consisted of: 19 males and 14 females aged between 0-4 years old; 14 males and 13 females aged between 5-9 years old; 12 males and 9 females aged between 10-14 year olds; two males aged between 15-19 years old; and one male and one female aged 20-24 years old (Figure 18).

The chi-square test was used to find out if there was a significant difference between the age groups of males and females within the living population (Dytham 2003, Hawkins 2009). At a 0.05% significance level the test found no significant difference (P =0.926) (Appendix 3f).

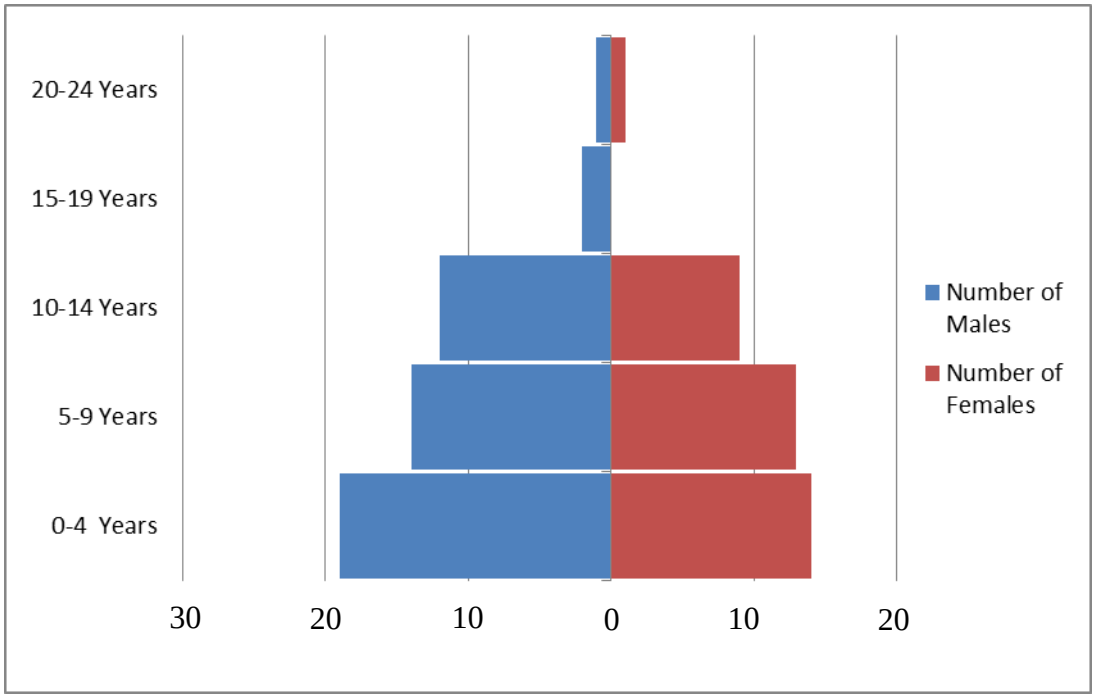

Figure 18: Age pyramid displaying the sex composition and age structure of the European living population of pygmy slow loris in 2011 (at 1st January). Population also includes three males and two females of unknown age. This graph shows the age class with the highest number of males and females was 0-4 years.

Table 4: Captive population data on nocturnal prosimians held within EAZA institutions between 1990 and 2012 (at 1st January). Average annual birth, death and natural increase rates were calculated on total number of births and deaths within the population: aye-aye - total births = 26, total deaths = 22, total infant deaths = 12; fat-tailed dwarf lemur - total births = 80, total deaths =78, total infant deaths = 14 ; Goodman's mouse lemur - total births = 85, total deaths = 11, total infant deaths = 0; grey mouse lemur - total births = 879, total deaths =772, total infant deaths = 152; grey slender loris - total births = 143, total deaths =174, total infant deaths = 58; and pygmy slow loris - total births = 215, total deaths = 243, total infant deaths = 80.

Species		Population size		Sex composition			Birth and death rates[1]			Rate of natural increase[1]	Total number of EAZA institutions holding species
Common name	Scientific name	Starting size	End size°	Number of males	Number of females	Number of unknown	Ave annual birth rate	Ave annual death rate	Ave annual infant mortality rate	Ave annual rate of natural increase	
Aye-aye*	*Daubentonia madagascariensis*	3	16	8	8	0	92.04	89.19	333.33	2.85	6
Fat-tailed dwarf lemur	*Cheirogaleus medius*	41	21	10	11	0	87.47	91.99	97.51	-4.51	4
Goodman's mouse lemur	*Microcebus lehilahytsara*	4	85	46	39	0	234.25	24.35	0.00	209.90	3
Grey mouse lemur	*Microcebus murinus*	162	217	103	100	14	176.94	151.89	166.29	25.05	29
Grey slender loris	*Loris tardigradus*	58	23	10	10	3	136.96	173.67	341.93	-36.71	5
Pygmy slow loris	*Nycticebus pygmaeus*	71	90	51	39	0	122.76	138.64	344.27	-15.88	26

* International captive population data ° Last available studbook record [1] per 1,000 individuals

Table 5: Overall variance in the starting population size and end population size of six European captive populations of nocturnal prosimian. Data collected from years 1990 to 2012.

Population	Population size Increased or decreased	Variance in number of individuals	Percentage of increase/decrease (%)
Aye-aye*	Increase	13	433.3
Fat-tailed dwarf lemur°	Decrease	-20	48.8
Goodman's mouse lemur[1]	Increase	81	2025
Grey mouse lemur	Increase	55	33.9
Grey slender loris°	Decrease	-35	60.3
Pygmy slow loris°	Increase	19	26.8

*International captive population ° last available studbook record was 2011

[1] period of analysis began in 1997

4.7 Causes of death

The recorded causes of the death within the international captive population of aye-aye, and the European captive population of grey slender loris and pygmy slow loris are given in the tables below (Table 6, 7, 8). These recorded causes of death were taken from the studbook records between the years 1990 - 2011.

Table 6: Reported causes of death within the international captive population of aye-ayes held within international zoological association institutions between the years 1990-2011.

Reported causes of death	Number of individuals	Percentage of total deaths (%)
Environmental/behaviour condition	1	4.55
Euthanasia	1	4.55
Infection	5	22.73
Premature birth	1	4.55
still birth	4	18.18
Unknown cause	10	45.45
Total	**22**	**100.00**

Table 7: Reported causes of death in captive populations of grey slender loris held within EAZA institutions between the years 1990-2011.

Reported causes of death	Number of individuals	Percentage of total deaths (%)
Environmental/behaviour condition	3	1.72
Euthanasia	15	8.62
Infection	7	4.02
Injury from exhibit mate	2	1.15
Malicious destruction (intentional destruction)	1	0.57
Old age	5	2.87
Premature birth	1	0.57
Self-inflicted injuries	1	0.57
Still birth	2	1.15
Unknown - bacterial	1	0.57
Unknown - cardiovascular	1	0.57
Unknown - Integumentary	1	0.57
Unknown - urinary	5	2.87
Unknown cause	129	74.14
Total	**174**	**100.00**

Table 8: Reported causes of death in captive populations of pygmy slow loris held within EAZA institutions between the years 1990-2011.

Reported causes of death	Number of individuals	Percentage of total deaths (%)
Died in transit	1	0.41
Environmental/behaviour condition	11	4.53
Euthanasia	29	11.93
Infection	11	4.53
Injury from exhibit mate	5	2.06
Malicious destruction (intentional destruction)	1	0.41
New growths/cancer	1	0.41
Old age	3	1.23
Premature birth	2	0.82
Still birth	7	2.88
Stranded	1	0.41
Unknown - cardiovascular	1	0.41
Unknown - digestive	7	2.88
Unknown - genetic/prenatal	2	0.82
Unknown - hemic/lymph/trauma	1	0.41
Unknown - Integumentary	1	0.41
Unknown - musculoskeletal	2	0.82
Unknown - reproductive	2	0.82
Unknown - urinary	4	1.65
Unknown cause	151	62.14
Total deaths	**243**	**100.00**

Table 9: Percentage of infant deaths compared to total deaths in six European captive populations of nocturnal prosimian. Data collected from years 1990 to 2012.

Population	Total deaths	Total infant deaths	Percentage of infant deaths (%)
Aye-aye*	22	12	54.5
Fat-tailed dwarf lemur°	78	14	17.9
Goodman's mouse lemur[1]	11	0	0
Grey mouse lemur	772	152	19.7
Grey slender loris°	174	58	33.3
Pygmy slow loris°	243	80	32.9

*International captive population ° last available studbook record was 2011

[1] period of analysis began in 1997

4.8 Statistical analysis of infant mortality rates

The Kruskal-Wallis test was used to determine if there was a significant difference between the average annual infant mortality rate of each population (Dytham 2003, Hawkins 2009). At a 0.05% significance level the test found there was no significant difference ($X^2 = 5.000$, df = 5, P = 0.416) (Appendix 2).

Part 1

Chapter Five

5.0 Discussion

I investigated the European captive populations of nocturnal prosimians and provided a current record of the populations that are part of captive breeding programmes within EAZA member institutes. The captive population data collected was then analysed to determine their demographic self-sustainability. In order for a captive population to be considered as demographically self-sustaining the number of births need to be equal to, or greater than the number of deaths (Hosey *et al*, 2009; Leus *et al* 2011, Riewald *et al* unpublished). The results of these findings are discussed in this chapter.

This study builds on the findings of Riewald *et al* (unpublished) who carried out rapid studies on the international captive population of aye-aye and the European captive population of grey slender loris. The researcher found both populations failed three sustainability categories. It also updates previously published research on the grey mouse lemur (Glatston 2001), which carried out an analysis on the population between the years 1990 and 1997. As previously mentioned in Chapter Two there were no captive population studies found in main stream literature on fat-tailed dwarf lemur, Goodman's mouse lemurs and pygmy slow loris, therefore this study provides the first recorded demographic data on these captive populations

5.1 Population development

Average annual birth rate in the international captive population of aye-aye was found to be greater than death rate indicating a demographically self-sustaining captive population (Hosey *et al* 2009). Statistical tests to determine if there was a significant difference between annual birth and death rates over the study period found no significant difference. The population was found to have increased by 433.3% over the study period (Table 5). Although this high increase in population size was found, the number of individuals within the international population was found to be small (16 individuals) and the average annual rate of natural increase was low (2.85 individuals per 1,000 population) (Table 4). Total population size at 1st January 2012 was 16 individuals and the rate of natural increase of the population was found to be 2.85 individuals per 1,000 population (Table 4). This supports

Riewald *et al* (unpublished) findings that growth rates within the captive population are low and total population size is small.

These results indicates that the captive population of fat-tailed dwarf lemur is not demographic healthy and the future viability of the captive population could be at risk. Total births were higher than deaths in this population (80 births, 78 deaths) (Table 4). However, there were four years (1997, 2005, 2009 and 2010) within this period when no births occurred (Figure 5). Average annual birth and death rates therefore found that the population had a higher average annual death rate (91.99) compared to birth rate (87.47) (Table 4). Results from the analysis also discovered a 48.8% decrease in population size over the study period and an average annual rate of natural increase of -4.51 per 1,000 population (Table 4, 5).

Results revealed the current captive population of Goodman's mouse lemur to be doing well. This population saw an extreme increase in size from the years 1997 to 2011 (2025%) (Table 5) and had an average annual rate of natural increase within the population of 209.9 individuals per 1,000 population (Table 4). The average annual birth rate of the population was found to be considerably higher than death rate (234.25, 24.35 respectively) (Table 4). A statistical test carried out on the difference between annual birth and death rates found a significant difference between these variables.

Previously published research on grey mouse lemurs revealed the population size declined between the years 1994 and 1997 (Glatston 2001). Glatston (2001) stressed the need for immediate action to take place in order to maintain a viable captive population in European zoos. Current study results show the population is now on the increase, with an average annual rate of natural increase of 25.05 individuals per 1,000 population and a 33.9% increase seen over the whole study period (Table 4, 5). Glatston (2001) reported a significant decline in the number of births between the years 1994-1997. Average annual birth rates in this study were now found to be higher than death rates (176.94, 151.89 respectively). No significant difference was found between annual birth and death rates over the study period. An increase in the total number of birth to deaths occurred within four years of the publication of Glatston's (2001) study (Figure 11). This result indicates this research prompted immediate action to be taken to manage the population effectively to help maintain a viable population in the long-term.

Results from this current study support Riewald *et al* (unpublished) findings that the European captive population size of grey slender loris is small and growth rates are low.

Riewald *et al* (unpublished) found this population failed three of five sustainability categories. The researcher suggested further analysis of the population should take place to determine accuracy within these preliminary results. This current study provided a more detailed analysis of the demographic health of this population. Results found the average annual death rate (173.67 individuals per 1,000 population) to be higher than birth rate (136.96 individuals per 1,000 population) (Table 4). The current population size was small (23 individuals) and had decreased in size by 60.3% over the study period (Table 4, 5). The average annual rate of natural increase was also shown to be decreasing by -36.71 individuals per 1,000 population (Table 4).

Initial results of the analysis of the pygmy slow loris captive population found an increase in the population size over the study period of 26.8% (Table 5). However, further analysis revealed the population is not doing well. The average annual death rate of the population outweighed birth rate and average annual rate of natural increase was decreasing by -15.88 individuals per 1,000 population (Table 4). The increase seen in population size over whole the study period may have therefore been a result of new individuals being brought into the population rather than captive births occurring within the existing population.

5.2 Sex and age structure of living population

I found no significant difference in the age classes of the males and females of each population. The sex ratio of a population affects the capacity in which the population can maintain genetic diversity (Rees 2011). The further this differs from a ratio of 1:1, the greater the difference between actual population size and effective population size (the number of individuals contributing to genes to the next generation). This means if there are a greater number of either males or females within a population then the effective population size decreases from the actual population size. The greater the difference in males to females, the bigger the decrease is between these population sizes (Rees 2011). As no significant difference was found between the age classes within the study populations this therefore indicates these populations have good capacity to maintain genetic diversity.

Results of the sex composition and age structure of this study were presented using age pyramids (Chapter 4.0). Through using this presentation method it is possible to show whether the structure of the living captive population is growing, stable or decreasing (Rees 2011).

Glatston (2001) reported that in 1997 the grey mouse lemur had an unstable age structure as the younger age classes are underrepresented. 14 years after this analysis on the population's age structure, the current study has revealed the structure of the living population to now be growing (Figure 12) (Rees 2011). The largest number of individuals within an age class of this captive population was found to be the youngest age class (0-4 years old). This result shows that the stability of the populations' age structure has increased since the last study, which is a promising result for the future sustainability of this population.

Age pyramids on the living populations of Goodman's mouse lemur and pygmy slow loris found the structures of these populations were also growing with the most individuals within an age class being the youngest in age and lowest number within an age class being the oldest in age (Figures 9, 18). These are also encouraging results for the future of these populations.

Although good news for the grey mouse lemur, Goodman's mouse lemur and pygmy slow loris, the aye-aye age structure was found to be not so promising. This study found the living captive population had an unstable structure and no females between the ages of 0-4 years old (Figure 3). This species reaches sexual maturity around 2.5 years old and gives birth to a single infant that requires an extended period of maternal care (Feistner and Carroll 1995, Winn 1994b). The small international captive population size (Table 4) that this species exhibits and absence of young females is a real concern for the future sustainability of this species in captivity.

Fat-tailed dwarf lemur and grey slender loris was also found to have an unstable age structure in their living populations (Figures 6, 15). Only two male and one female were aged between 0-4 years old in the fat-tailed dwarf lemur population (Figure 6). The grey slender loris population had twice as many females to males in its youngest age class (0-4 years old) (Figure 15). Both of these species have a small European captive population size (Table 4) along with an age structure of an unstable nature. These results are especially concerning for the fat-tailed dwarf lemur as they are considered to have a monogamous social arrangement (Fietz 1999).

There was no published study in mainstream literature found on the sex composition and age structure of the international captive population of aye-aye and the European captive populations of Goodman's mouse lemur, fat-tailed dwarf lemur, grey slender loris and pygmy slow loris. Therefore the results on the age structure of these captive populations provide the first recorded demographic data for these prosimian species.

5.3 Causes of death/ morbidity

Fitch-Snyder and Schulze (2001) found trauma (including bite wounds from exhibit mates) to be the major causes of morbidity and mortality in lorises housed at San Diego Zoo and Duke University Primate Center. Deaths from bite wounds were reported at both these two institutions (Fitch-Snyder and Schulze 2001). Prescott 1980 cited by Debyser (1995) found traumatic insults especially bite wounds occurred to juveniles from either parents or cage mates. Traumatic insults were found to be one of three main factors linked to infant mortality in juvenile mortality (Debyser 1995). Results from this current study show two deaths in grey slender lorises and five deaths in pygmy slow lorises were from injury from an exhibit mate within European institutions. Fitch-Snyder and Schulze (2001) suggest adjacent housing should be designed so that physical contact between animals housed in separate enclosures is unable to occur.

I found the highest reported cause of death (after Euthanasia) in aye-aye, grey slender loris and pygmy slow loris was infection (Tables 6, 7, 8). Fitch-Snyder and Schulze (2001) reported a juvenile pygmy lorises and one slow loris died from septicaemia as a result of a bite wound. Seventeen cases of bite wounds that required medical attention were reported in captive pygmy and slow lorises at San Diego Zoo and Duke University Primate Center (Fitch-Snyder and Schulze 2001). Many of these individuals developed cellulitis and abscesses after these injuries (Fitch-Snyder and Schulze 2001).

Fitch-Snyder and Schulze (2001) found that captive lorises have historically suffered chronic health problems such as periodontal (gum) disease. They found that dental disease was a significant cause of morbidity (Fitch-Snyder and Schulze 2001). Captive primates are regularly found to suffer with tooth decay due to consuming large amounts of sugary fruits (Rees 2011). Wiens *et al* (2006) found wild slow lorises in West Malaysia spend the largest amount of their time eating phloem sap (34.9%), followed by floral nectar and nectar-producing parts (31.7%) and less amount of time eating fruit (22.5%). Nekaris *et al* (2010) found exudates are a key food sources for four species of loris (*Nicticebus councang, N. bengalensis, N.javanicus and N. pygmaeus*). Starr and Nekaris (2013) later found pygmy slow lorises to be obligate gummivores. Absence of exudates in captive diets is thought to cause dental disease in pygmy slow loris (Streicher 2004 cited by Starr and Nekaris 2013). Streicher (2004) cited by Starr and Nekaris (2013) found pygmy slow loris only fed on European captive diets suffered recurrent dental problems but wild-caught species who able to gouge on branches did not present any dental problems. Fitch-Snyder and Schulze (2001)

suggest in their husbandry guidelines for captive lorises that commercial gum can be provided to captive lorises; however it is not mentioned as an essential item for captive diets.

5.4 Infant mortality

This study found no significant difference within the average annual infant mortality rates between the captive populations. The highest infant mortality rates occurred in the grey slender loris and pygmy slow loris (341.93, 344.27 respectively), these results show that over one-third of births per 1,000 population results in death within the first year of life (Table 4). Juvenile mortality (from conception until weaning) is considered as a serious concern in captive prosimian populations (Debyser 1995). Total infant mortality in the world captive population of black-and-white ruffed lemurs was 36.6% (Schwitzer and Kaumanns 2009).

Debyser (1995) found prosimian juvenile mortality ranged between 25-45%, with lorisiformes suffering the highest juvenile mortalities, while lemuroids were generally in the lower percentages (Debyser 1995). The result of this current study supports Debyser (1995) as findings show the grey slender loris and pygmy slow loris populations suffer with higher infant mortality rates compared to the lemur study populations.

Although lemuroids were found to have lower infant mortality rates than lorises. This current study did find the average annual infant mortality in the captive aye-aye population to be high (333.33 individuals per 1,000 population), with 54.5% of total deaths over the study period being infants (Table 4, 9). This study also found the population to suffer with low growth rates (2.85 individuals per 1,000 population), these low growth rates and high average annual infant mortality rate supports the findings of Riewald *et al* (unpublished).

Debyser (1995) found that several factors are often involved in causing mortality in juvenile prosimians, the most commonly linked factors were stress, maternal neglect, and traumatic insults. Prosimians are considered to be highly sensitive to stress (Debyser 1995). Haring and Wright (1989), Roberts (1994), Hirota *et al* (2011) found many juvenile tarsiers die before reaching weaning age due to accidental injury or maternal neglect and Bristol Zoo Gardens, in Bristol, England hand-reared two aye-aye infants due to maternal neglect (Pers Obs.). Petter (1975) and Glatston (1981) as cited by Debyser (1995) reported that light, humidity and design of the enclosure are important factors in allowing prosimians to carry out mothering behaviours. Management factors were found to play a role in neo-natal mortality in captive galagos (Debyser 1995).

5.5 Limitations

There were a number of known limitations to the studbook data analysed in this study.

Unfortunately studbook data for populations of galagos, tarsiers, potto and angwantibo's were unable to be analysed as part of this study. As previously discussed in Chapter Two the European captive populations of galagines are undergoing taxonomic revision and studbooks currently do not exist. Studbook data was also unavailable for captive populations of tarsiers as this species have been unsuccessfully maintained in captivity. Studbook data on European captive populations of potto and angwantibo's were also unable to be analysed, as information on these species in captivity is extremely limited.

Individuals born in the wild have unknown birth dates, this was also found to be the case with some captive born individuals. Some of these individuals have been given an approximate dates of birth by the studbook keeper; this approximate data was used in the data analysis.

The studbook data consists of a number of approximated start dates in captivity; these estimated start dates were used in the study. Individuals with an unknown start date in captivity were analysed using the first recorded date that the animal was transferred to another institution. These individuals may have been in the captive population longer than the time recorded in the analysis.

A small number of studbook records within each population had an unknown date of death. These records were not included when calculating the total population size each year as it was not possible to determine how long the individual had been living in captivity.

Fat-tailed dwarf lemur and the pygmy slow loris captive populations both consisted of individuals with an unknown date of birth with no approximates given. As the age of these individuals was not able to be determined they were excluded from the age structure analysis. The grey mouse lemur and grey slender loris had individuals of unknown sex within their populations. These individuals are likely to be juveniles whose sex is yet to be determined (Rees 2011). These individuals of unknown sex were not able to be included within the age structure analysis.

The records of causes of death for each population are extremely limited with many causes given as 'unknown'. Therefore a statistical analysis on this data was unable to take place. Reported causes of death have been displayed as a list within the results. This was also found to be the case in a study by Ange-Van Heugten *et al* (2010) who reviewed the population trend and mortality causes in captive woolly monkeys (*Lagothrix spp.*).

Studbooks records include individuals which have been transferred to private collectors or non EAZA zoological institutions. Records for these individuals are incomplete as no data was able to be recorded once individuals were transferred outside EAZA institutions.

Despite these limitations a detailed analysis of the demographic health of the current captive populations of nocturnal prosimians is considered important as published literature on this topic is extremely limited. The results from this study provide a current record of these populations and increasing the knowledge base could help manage these populations effectively, increasing their sustainability in the long-term (Baker 2007).

5.6 Future work

I analysed the demographic health of captive prosimian populations. Future works should involve a genetic analysis of these populations. An analysis of both the demographic and genetic health of these populations will provide a fuller picture of the future viability of the populations (Baker 2007). A genetic analysis may also help to determine the causes of low growth rates within the populations. Glatston (2001) found that inbreeding within the European captive population of grey mouse lemur had a negative impact on the reproductive output.

Once taxonomic classification of the captive populations of galagines has been determined and studbooks have been set up, further research should be carried out to determine the demographic and genetic health of these populations, in order to manage them effectively in the future. Further research on captive populations of pottos and angwantibos is also recommended once data on these species are available for analysis.

Published research highlighted that the captive management of prosimians needs to be appropriate to the species and fulfil their species-specific requirements in order for captive populations to be maintained successfully (Fitch-Snyder and Schulze 2001, Kaumanns *et al* 2008, Roberts and Kohn 1993, Schwitzer and Kaumanns 2009, Wright *et al* 1989). The

second part of this study will focus specifically on two captive loris populations held within European zoos (grey slender loris and pygmy slow loris) to determine if current husbandry methods affect their breeding success. Death rates within these populations were found to be higher than birth rates, infant mortality rates were the highest of all study populations and their average annual rates of natural increase were found to be decreasing.

Part 1

Chapter Six

6.0 Conclusions

This study investigated the current captive populations of nocturnal prosimians within European Zoos. Six captive populations (aye-aye, fat-tailed dwarf lemur, Goodman's mouse lemur, grey mouse lemur, grey slender loris and pygmy slow loris) within EAZA captive breeding programmes were analysed to determine if they were considered as demographically self-sustaining. This study also provides a current record of each of these captive populations. It builds on limited research in the topic area and provides the first reported demographic data on European captive populations of fat-tailed dwarf lemur, Goodman's mouse lemur, grey mouse lemur and pygmy slow loris.

No significant difference in age structure and sex composition within each population was found, suggesting these populations have good capacity to maintain genetic diversity. Results also discovered average annual rates of infant mortality were not significantly difference between the study populations.

The captive populations of aye-aye and fat-tailed dwarf lemur were found not to be demographically self-sustaining. They were found to have a small population size, a low or decreasing rate of natural increase and an unstable living population structure. The captive aye-aye population was also found to have a high infant mortality rate.

The European captive population of Goodman's mouse lemur was found to be self-sustaining. The annual birth rates were significantly higher than death rates and there were no reported infant deaths over the whole study period. The living population was found to have a growing population structure. The grey mouse lemur population was also found to have an increasing population trend and the living population structure was stable.

Results indicate the European captive populations of grey slender loris and pygmy slow lorises are not self-sustaining. Both populations have higher death rates than birth rates and decreasing rates of natural increase. They were also found to be suffering with high infant mortality rates. To maintain viable captive populations of these threatened species in captivity urgent action is required to address these issues.

Results found the highest reported cause of death (after Euthanasia) in aye-aye, grey slender loris and pygmy slow loris was infection. Fitch-Snyder and Schulze (2001) found bite wounds to be common in lorises, with many animals developing cellulitis and abscesses from these injuries. Fitch-Snyder and Schulze (2001) also found that captive lorises have historically suffered chronic health problems such as periodontal (gum) disease.

Literature reviewed as part of this research highlighted that prosimians species require the appropriate management in order to be maintained successfully in captivity (Fitch-Snyder and Schulze 2001, Kaumanns *et al* 2008, Roberts and Kohn 1993, Schwitzer and Kaumanns 2009, Wright *et al* 1989). Further work on current husbandry methods used for these species could determine if these factors play a role in their breeding success.

Part 2

Chapter One

1.0 Literature review

Results from the first part of this study revealed that the European captive populations of grey slender loris and pygmy slow loris are not self-sustaining. The grey slender loris population is small (23 individuals) with a decreasing rate of natural increase (-36.71 individuals per 1,000 population) (Table 4). Although the pygmy slow loris captive population was found to be larger in size (90 individuals), it was also discovered to be suffering from a decreasing rate of natural increase (-15.88 individuals per 1,000 population) (Table 4). Average annual infant mortality rates for both populations were found to be high (341.93, 344.27 respectively) (Table 4). In the wild, populations of these species are considered threatened and have decreasing population trends (grey slender loris has an IUCN Red List status of Least Concern; pygmy slow loris has an IUCN Red List status of Vulnerable) (IUCN 2013). Maintaining a viable captive population of these species in captivity is therefore considered to be important in order to provide a safeguard against their extinction in the wild.

As previously mentioned (Part 1, Chapter One), good captive management techniques play an important role in maintaining the long-term viability of captive populations of exotic animals (Baker 2007). The second part of this research aimed to look into why these captive populations are not doing well by determining if current husbandry methods affect their breeding success. This current chapter will review species-specific requirements and the current husbandry recommendations for lorises.

1.1 Captive management

In order for zoos to become a member of the European Association of Zoos and Aquaria (EAZA) they need to comply with codes of practice and standards that are set by the association. The accreditation process is thorough and applicants need to demonstrate they fulfil these requirements, many of which relate to the welfare of captive animals. EAZA policy documents include ‘Minimum standards for accommodation and the care of animals in zoos and aquaria’ and ‘Code of ethics’ (EAZA 2011). These zoological institutions are also expected to follow the IUCN technical guidelines on the management of ex-situ populations for conservation (EAZA 2011). These guidelines set out how organisations responsible for ex-situ populations should manage these populations to maximise their conservation value

(EAZA 2011, Rees 2011). Institutions should also follow species-specific housing and husbandry guidelines for all animals that are part of captive breeding programmes (Hosey *et al* 2009). These guidelines include the animal's requirements for housing, handling, husbandry, health, diet and breeding (Rees 2011). Results from published studies comparing actual zoo practice to species management guidelines found that this guidance was generally followed (Eriksson *et al* 2010, Fuller *et al* 2012)

Although housing and husbandry guidelines are considered as a requirement for all animals within captive breeding programmes, these documents were found to be limited to a small number of species (Hosey *et al* 2009). Hosey *et al* (2009) only found 24 of these guidelines when reviewing the International Species Information System (ISIS). ISIS is a central electronic location for storing these documents and can be accessed by zoos and aquariums (Hosey *et al* 2009). The comprehensiveness and quality of the information within these guidelines was also found to differ (Hosey *et al* 2009). Melfi *et al* (2007) cited by Melfi (2009) suggests recommendations in zoo association housing and husbandry guidelines are not supported by empirical evidence. In unsuccessful captive breeding programmes scientific research on managing these captive populations could be being poorly translated in management plans or implemented in zoos (Lee and Wilcken 2009). Melfi (2009) suggests that our knowledge of what is meant by good welfare is limited to an assessment of a small amount of variables and is biased to a few species. The effect of space and championship is used as a measure of good animal welfare more than other variables such as climate that may have a more significant effect on the welfare of captive animals. Melfi (2009) suggests this lack of knowledge inhibits zoos from providing their captive animals with the best welfare possible.

In order for zoos to effectively maintain e*x-situ* populations over the long-term good management needs to be in place (Baker 2007). A good management strategy could save an endangered species from extinction (Glatson, 2001). Robert and Kohn (1993) suggest successful management of tarsiers (a prosimian species that has been unsuccessfully maintained in captivity) could be obtained if basic biological requirements are recognised and accommodated within management plans. Results from published studies found husbandry parameters affect breeding success in captive penguins and flamingos (Blay and Côté 2001, Pickering *et al* 1992). Blay and Côté (2001) found hatching success in captive Humboldt Penguins (*Spheniscus humboldti*) increased with increasing size of the enclosure pool. Large flocks of captive flamingo in Britain and Ireland had higher breeding success and bred more frequently than smaller flocks (Pickering *et al* 1992).

1.2 Captive requirements of lorises

An extensive husbandry manual on the management of captive lorises was published twelve years ago (Fitch-Snyder and Schulze 2001). At the time of writing this manual little was known about the species specific requirements as long-term field studies on these species were extremely limited. Fuller *et al* (2012) carried out a study on the husbandry practices used for captive lorisid primates in 29 North American zoos and related facilities. The study looked into whether these facilities followed existing guidelines for the species (Fuller *et al* 2012). They found this generally was the case in regard to the physical design of loris exhibits and enriched environments.

1.2. Habitat use

Lorises are arboreal and will use the locomotive behaviour of cantilevering (bridging or extending the body) to move through their habitat rather than actively leap from branch to branch (Nekaris and Bearder 2007). In order to carry out this behaviour dense vegetation is required to allow animals to move around the forest (Nekaris and Bearder 2007). Husbandry guidelines for the species recommend enclosure furniture should provide the animal with a continuous pathway around the whole enclosure without the need to come to ground (Fitch-Snyder and Schulze 2001).

Fitch-Snyder and Schulze (2001) recommend enclosures should be furnished with a variety of sizes of branches at horizontal, vertical and oblique angles. Horizontal branches are highly recommended as they allow the species to carry out natural behaviours such as breeding, resting and sleeping (Fitch-Snyder and Schulze 2001, Schulze and Meier 1995). Horizontal branches with lateral support are favoured by the species for sleeping (Schulze and Meier 1995). Lorisiforms are found to generally select a size of substrate that relates to their own body weight, with smaller animals selecting smaller branches and larger individuals selecting stronger bigger branches (Nekaris and Bearder 2007). Branches with large diameters and vertical trunks are not recommended as lorises find it difficult to maintain a good grip (Fitch-Snyder and Schulze 2001). Curtis (1992) found captive aye-ayes had a preference for enclosure substrates, females preferred ropes with a small diameter, while males had a preference for medium-sized branches.

The recommended minimum enclosure size for captive lorises given is 2.5m x 2.5m x 2.5m (15.6 m³) (Fitch-Snyder and Schulze 2001). Daschbach *et al (*1982/83) found cage size affected activity levels in slow lorises, with animals housed in smaller enclosures being less active than ones kept in larger sized enclosures. Results from Fuller *et al* (2012) found pygmy slow lorises enclosure in North American zoos and related facilities were generally housed in enclosures larger in size than recommended guidelines. However, slender lorises were housed in enclosures smaller in size than the recommended guidelines.

A study on another lorisid species (*Perodicticus potto*) found furnishing their captive enclosure with non-synthetic natural materials such as live plants, grapevines and a hollow tree increased activity levels, promoted additional species-specific behaviours and prompted the species to carry sexual behaviours (Frederick and Fernandes (1996). Blay and Côté (2001) found particular nesting substrate affected breeding success in humboldt penguins. Nest boxes with sand and gravel resulted in highest chick productivity. Fitch-Snyder and Schulze (2001) recommend an enclosure to have several suitable nest sites as lorises can vary the location where they sleep. Both plant foliage and boxes are recommended for these sites (Fitch-Snyder and Schulze 2001). Field studies found lorises to use vine tangles and dense scrub and branches as sleep sites (Nekaris and Bearder 2007). From the 29 institutions surveyed in North American nearly all provided nest boxes within their loris enclosures (Fuller *et al* 2012).

1.2.2 Environmental conditions

Trent *et al* (1977) carried out a study on the effects of illumination on three wild caught slow lorises. They found the animals increased their activity levels during times where lighting levels simulated twilight and had lower activity levels during times where illumination replicated moonlight (Trent *et al* 1977). Starr *et al* (2012) also found moonlight affects activity levels in pygmy slow loris. Starr *et al* (2012) investigated the effects of temperature and moonlight on activity levels, results found the animals were more active on bright warm temperatures and less active on cold bright nights. However, temperature did not affect activity levels on dark nights; the animals remained active during these times in both lower and higher temperatures.

Frederick and Fernandes (1994) found temperature had no effect on activity levels in two captive pottos (*Perodictus potto*). However, humidity significantly affected activity levels in

these captive individuals (Frederick and Fernandes 1994). Petter (1975) and Glatson (1981) cited by Debyser (1995) reported that light, humidity and design of the enclosure are important factors in allowing prosimians to carry out species-specific sexual and mothering behaviours. Recommended environmental conditions within loris enclosure is a temperate range of 65.5°F – 85.5°F (18.6°C - 29.7°C) and relative humidity (RH) levels between 40%-60% (Fitch-Snyder and Schulze 2001).

Fuller *et al* (2012) found night-time lighting within loris enclosures in North American institutions varied in types of light sources and colours. Frederick and Fernandes (1994) proposed that pottos may see blue light as lighter than red. Fitch-Snyder and Schulze (2001) recommend a natural density acetate filter to simulate moonlight but if this is unavailable than red light should be used as an alternative.

1.2.3 Social behaviours

During active periods slender lorises are found to carry out locomotive behaviours solitarily or in pairs (Schulze and Meier 1995). Goonan (1993) found a group of one male and three female captive slender loris (*Loris tardigradus*) would separate during the night for up to six hours but would then group together to sleep. Nekaris (2003) also found this to be the case with three subspecies of wild slender loris (*Loris lydekkerianus lydekkerianus, L. l. nordicus and Loris tardigradus tardigradus*) who were all found to sleep in social groups. Captive *L. t. nordicus* were also found to sleep in family groups (Schulze and Meier 1995). Nekaris (2003) observed both adult males and females in three subspecies of slender loris grooming each other nearly every night (Nekaris 2003). Mutual allogrooming in slender lorises was also observed by Goonan (1993). Husbandry guidelines recommend captive lorises should be kept as a breeding pair or mother with immature offspring (Fitch-Snyder and Schulze 2001).

Male lorises are found to have a larger home range than females (Fitch-Snyder and Schulze 2001, Nekaris and Bearder 2007). Nekaris (2003) found Mysore slender lorises to have a single male/single female or single male/multiple female social system. Female Mysore slender lorises exhibit territorial behaviour and have limited overlap in their home ranges (Nekaris 2003, Nekaris and Bearder 2007). Groups of greater slow loris (*Nycticebus coucang*) often consist of one adult male, two females and their immature offspring (Nekaris and Bearder 2007). Husbandry guidelines recommend enclosures housing more than one loris should be larger in size than when housed singly (Fitch-Snyder and Schulze 2001).

Social housing is considered beneficial in the species as it can provide more stimulation than when housed solitary (Fitch-Snyder and Schulze 2001).

Studies relating to the use of olfactory communication in lorises is limited (Nekaris and Bearder 2007). Welker (1973) and Harcourt (1981) cited by Nekaris and Bearder (2007) mention how lorisiforms use specialist scent gland and urine to communicate. A study by Fisher *et al* (2003a) found that scent marking by male pygmy slow loris plays an important role in the female's reproductive behaviour. Izard and Rasmussen (1985) and Goonan (1993) both observed urine marking in female slender loris prior to copulation. Fisher *et al* (2003b) found female pygmy slow loris could differentiate between different male's scents with a strong preference towards familiar male scent when compared to a scent from a novel male. Prescott (1980) cited by Debyser (1995) found scent-marking in many lemur species is related to the synchronization of oestrus and parturition, which is an important factor in the breeding. The husbandry guidelines for lorises do not recommended frequent cleaning; this practice can cause unnecessary stress to the animals. However, branches within the enclosure should be replaced or cleaned every few weeks to avoid skin irritations from a build-up of urine (Fitch-Snyder and Schulze 2001). Fuller *et al* (2012) suggests an evaluation on the impact of cleaning methods on olfactory communication is urgently needed.

1.2.4 Reproductive behaviours and parental care

Weisenseel *at al* (1998) found one wild pygmy slow loris exhibited signs of oestrous at 9 months old. Husbandry guidelines state the species usually conceive at between 1-1/2 years of age (Fitch-Snyder and Schulze 2001). Fitch-Snyder and Schulze (2001) reports that a captive female pygmy slow loris gave birth at 20 months old and the species usually produce their first offspring by two years of age. Ramakrishna and Prasad (1967) suggested female slender loris (*L.t. lydekkerianus*) also give birth to their first offspring when they are approximately two years old. A later study carried out on a captive breeding colony of slender loris (*L. t. malabaricus*) found one female to give birth at 17.6 months of age.

Copulation in lorises takes place in a suspended horizontal position with the male being fully supported by the female (Fitch-Snyder and Schulze 2001, Schulze and Meier 1995). Copulation in slender lorises was found to occur several times in one night, with each bout lasting around 2-3 minutes (Goonan 1993). Husbandry guidelines recommend enclosure furniture to consist of horizontal branches to allow for these behaviours to be performed (Fitch-Snyder and Schulze 2001).

Fitch-Snyder and Jurke (2003) presented preliminary findings that a higher number of births occurred in pygmy slow loris that were housed together prior to the onset of oestrus compared to pair that were mixed once oestrus had already commenced. Fitch-Snyder and Schulze (2001) recommend housing lorises in breeding pairs.

As previously mentioned (Part 1, Chapter 2.0) lorises are found to give birth to singletons or twins (Izard and Rasmussen 1985, Nekaris 2003, Radhakrishna and Singh 2003, Nekaris and Bearder 2007). Slender loris infants are fully dependent on their mother when new born and have little fur (Fitch-Snyder and Schulze 2001, Goonan 1993). In captivity the species was found to move independently from the mother at 21-38 days old, but this was for only small amounts of time and they stayed in close proximity to the mother throughout (Goonan 1993). The infant was carried by the mother until this time (Goonan 1993). Nekaris (2003) also found that the slender loris infants were carried by the female for the first four weeks of its life. In captivity, weaning in slender loris infants occurred at 66-71 days old (Goonan 1993).

The behaviour of infant parking is found to take place in lorisid primates (Nekaris and Bearder 2007). This practice involves the mother parting from her infant while she carries out foraging behaviours solitarily (Nekaris and Bearder 2007). During this time the mother leaves the infant on a branch from dusk until dawn (Nekaris and Bearder 2007). Infant parking in slow lorises (Nycticebus bengalensis) and pygmy slow lorises was observed from as early as week one after birth (Fitch-Snyder and Ehrich 2003). However, infant parking in a captive slender loris was found to occur at a slightly older age (3-5 weeks post-partum) (Goonan 1993). Nekaris (2003) observed female Mysore slender lorises parking their infants from around four weeks of age. Radhakrishna and Singh (2004) observed infant parking from three weeks old with the mother leaving the infant from dusk to dawn.

1.2.5 Diet

Barrett (1984) as cited by Fitch-Snyder and Schulze (2001) found slow lorises in the wild spent the largest proportion of their time feeding on fruit. A later study carried out on 33 slow lorises in West Malaysia between the years 1995-99 found their diet consists of five main food types: floral nectar and nectar-producing parts, phloem sap, fruits, gum and arthropods (Wiens *et al* 2006). Wiens *et al* (2006) found the largest amount of their time feeding was spent eating sap (34.9%), floral nectar or nectar-producing parts (31.7%) and fruit (22.5%).

Study results found no diet differences between the dry and rainy seasons (Wiens *et al* 2006). Wiens and Zitzmann (2003) reported the diet of the infant slow loris consists mainly of nectar, gum and sap, with fruit making up only a small portion of their diet.

Tan and Drake (2001) reported the first exudate eating behaviour and tree-gouging in pygmy slow loris suggesting they may be specialised gummivores. Starr and Nekaris (2013) later found pygmy slow lorises to be obligate exudativorous primates. They recorded the species eating exudates in 76 of 168 feeding observations of wild pygmy slow lorises in eastern Cambodia (Starr and Nekaris 2013). Nekaris *et al* (2010) found exudates are a key food sources for four species of loris (*Nicticebus councang, N. bengalensis, N.javanicus and N. pygmaeus*). It is suggested that to prevent periodontal diseases captive environments should allow lorises to carry out gouging behaviours (Nekaris *et al* 2010). Huber and Lewis (2011) stress the importance of providing gum-based enrichments for captive gummivores to allow them to carry out natural behaviours.

At the time of writing the husbandry guidelines, research on the nutritional requirements for captive lorises was extremely limited (Fitch-Snyder and Schulze 2001). Fitch-Snyder and Schulze (2001) suggest feeding gum to lorises through gum feeding devices or spreading the substance on branches within the enclosure. However, the guidelines do not stipulate a specific amount that should be made available to the animal (Fitch-Snyder and Schulze 2001). Captive diets for lorises were reviewed within the husbandry manual, these were found to mainly consist of ‘produce’ (fruit and vegetables), specialist primate complete feed and a small amount of insects (Fitch-Snyder and Schulze 2001). Fitch-Snyder and Schulze (2001) stress the need for further research in this area in order to provide optimal dietary and nutritional requirements for these species.

Part 2

Chapter Two

2.0 Methodology

2.1 Study Subjects

This part of the research focused specifically on the European captive population of grey slender loris (*Loris lydekkerianus*) and pygmy slow loris (*Nycticebus pygmaeus*). As previously mentioned (Part 2, Chapter One), these nocturnal prosimian species are considered threatened in the wild with an IUCN Red list conservation status of Least Concern and Vulnerable.

2.2 Study site

EAZA member institutions that house the European captive populations of these species are located throughout Europe. The last available studbook records for these populations identified 31 zoos that hold the study species (Table 4). These institutions are located in 12 different European countries (Belgium, Czech Republic, England, France, Germany, Hungary, Latvia, Poland, Slovakia, Spain, Sweden and Switzerland). In order to obtain membership of EAZA these zoos have to demonstrate that they comply with the association's standards and codes of practice in relation to housing animals in zoos and aquariums (EAZA 2011). Guidelines include a code of ethics, minimum standards of accommodation and care, and standards on education and research (EAZA 2011).

2.3 Ethical Considerations

This research does not involve any contact with animals, changes to animal enclosures or feeding regimes and therefore will not cause any foreseen distress, pain or suffering to animals that would lead to ethical concerns (I.S.A.E 2012). As this study is part of an MSc by Research thesis, the submission of an E2U form to the University Research Ethics Committee (UREC) was not a requirement (Wilson, M. Pers comm.). However, as this research consisted of an element of human participation in the form of a questionnaire an Oxford Brookes University HSS.E2 form (Application for ethics approval for a research project involving human participants) was completed and approved by the Director of Studies (Appendix4). Approval was granted through the completion of an E3 decision form (Appendix5).

The University's Code of Practice of Ethical Standards for Research involving Human Participants was followed. The research method used was found to present no potential adverse effects to the participants as they were not the subject of the research. The questionnaire was emailed to each participant. No consent form was required for this distribution method as consent was implied by returning the questionnaire. Participants were informed that all data supplied will be treated as confidential and presented in such a way that the name of the participant cannot be identified. All participating European zoos will receive feedback consisting of a copy of the results and recommendations of this study.

2.4 Materials

This research was conducted using a specifically-designed questionnaire. This survey method is often used to conduct multi-zoo research (Hosey *et al* 2009). The British and Irish Association of Zoos and Aquariums (BIAZA) Zoo Research Guidelines for surveys and Questionnaires was consulted when designing the questionnaire (Plowman *et al* 2006). Published studies that used this research material to collect husbandry data were also consulted (Blay and Côtés 2001, Eriksson *et al* 2010, Fuller *et al* 2013, Pickering *et al* 1992, Taylor and Poole 1998). To tailor the questions specifically to captive lorises, the husbandry manual for these species was reviewed (Fitch-Snyder and Schulze 2001). The questions that were given within the questionnaire related to the captive population, husbandry routines, enclosure dimensions, furniture and environmental conditions (lighting, air temperature, and humidity) and breeding routines (Appendix 6).

2.5 Data collection

The specifically-designed questionnaire was circulated to all known EAZA institutions housing grey slender and pygmy slow lorises. An identical questionnaire was distributed to each zoo in order to standardise the project results. The distribution list for the questionnaire was retrieved from the studbook data collected in Part 1 (Chapter Two). This list consisted of 30 separate zoological institutions located in 12 different European countries (see Section 2.2).

An introductory email introducing the research and asking for their support was sent to each zoo on the distribution list. This email included a letter of support from the EAZA Prosimian TAG Chair (Appendix 7). Respondents agreeing to help with the research were then sent the

questionnaire by email and asked to complete the document within a specified timeframe. This method of circulation was recommended by Plowman *et al* (2006) as it would be easier for the zoo to get the questionnaire to the most relevant person and less likely to become separated from its cover letter. The respondent was offered the opportunity to return the completed questionnaire by email or through the post depending on what was most convenient. The address details of the researcher were included within the questionnaire in case this method was preferred. Participants who did not return the questionnaire within the set timeframe were sent polite follow up emails as a gentle reminder (Plowman *et al* 2006). Fuller *et al* (2013) used this method to increase their response rate when conducting a survey of husbandry practices of lorisid primate in North American zoos and related facilities.

Published studies looking into how management factors affect breeding success used a questionnaire as their method of data collection (Blay and Côtés 2001, Pickering *et al* 1992, Taylor and Poole 1998). Blay and Côtés (2001) found hatching success in humboldt penguins (*Speniscus humboldti)* increased with the increasing pool size and chick productivity was highest when the substrates sand and gravel were used in nest boxes. Pickering *et al* (1992) found captive flamingo flocks had a high breeding success when kept in larger flocks. Hosey *et al* (2009) references Pickering *et al* (1992) as a good example of this type of data collection method.

2.6 Data analysis

In order to fulfil the aims of this research the results from the questionnaires were analysed to determine if husbandry parameters affect breeding success in captive lorises. The breeding success of each institution was calculated using the formula below (Carlstead *et al* 1999, Taylor and Poole 1998). Date range used for this calculation was: 1st January 1990 to 31st December 2012. The year 1990 was chosen as the start date because EEPs were first established in this year (Kaumanns *et al* 2008). Data for this calculation were collected using two methods: studbook records collected from Part 1 (Part 1, Chapter Two); population data collected within the husbandry questionnaire.

<u>Breeding success formula</u>

Total number of live births/number of years that mature female animals (over 2 years) were kept at the institution = breeding success of institution.

The following husbandry data from the completed questionnaires were analysed: number of lorises currently kept at each institute; captive diets (contents and dietary routines used); frequency of cleaning; enclosure areas (size and access to outdoors); enclosure furniture (fixed furniture and nest boxes); environmental conditions inside enclosure (temperature, humidity and lighting); presence of other species within enclosure and breeding routines (breeding pair continuously housed to together/mixed only for breeding). Taylor and Poole (1998) used questionnaire data on enclosure areas and feeding practices to compare the breeding success of captive Asian elephants in different institutions located throughout Asia, Europe and North America. Carlstead *et al* (1999) also used enclosure area when comparing reproductive success to housing facilities in captive black rhinos. Results of their study found a positive correlation between enclosure area and reproductive success (Carlstead *et al* 1999). They also compared environmental features of the animal's enclosure such as physical facilities and climate (Carlstead *et al* 1999).

2.7 Statistical Analysis

The computer software package IBM SPSS Statistic Version 19.0 was used to carry out statistical tests on the collected questionnaire and population data.

Data collected from this survey were statistically analysed to determine if there was a relationship between husbandry parameters and breeding success. The linear regression test was used for this analysis. This test was chosen as it investigates the relationship between two variables (Dytham 2003, Hawkins 2009). Linear regression tests were used in a study by Blay and Côtés (2001) to determine the optimal breeding conditions for the humboldt penguin (*Speniscus humboldti*). As previously mentioned (Section 2.5), results from this published study found the size of pool and nest box substrate related to hatching success (Blay and Côtés 2001).

The Kendall rank-order correlation test was carried out on the non-parametric husbandry questionnaire data to determine if the was a correlation between breeding success and these husbandry variables (Dytham 2003).

Results from this current study along with previously published research were then used to make husbandry recommendations that could help improve captive breeding success of the grey slender loris and pygmy slow loris. Results and recommendations will be distributed to

all European zoological institutions holding these species and the EAZA Prosimian Taxonomic Advisory Group (TAG).

Part 2

Chapter Three

3.0 Results

An identical husbandry and breeding questionnaire was circulated to 30 EAZA accredited European zoos that house grey slender and pygmy slow lorises. 20 institutions completed this questionnaire resulting in an overall 66.7% response rate. A further two institutions that were contacted as part of the study informed the author that they no longer kept the species. One of these institutions used to house grey slender loris, the other housed pygmy slow loris. All participating institutions answered the majority of questions given within the questionnaire. The results of this collected data is summarised below. Please note each zoo has been given a zoological institution number in order to provide anonymity to the participating institutions. This number also allows the results from individual zoos to be easily identified.

3.1 Enclosure area and furniture

Nineteen study institutions provided measurements of the size of their loris enclosures (Table 10, Figure 19). Results found lorises were kept in a variety of different sized enclosures (Figure 19). The largest mean enclosure volume was 160m³ (institute 18), the smallest average enclosure volume was 1.0 m³ (institute 7), both of which housed pygmy slow loris. The mean enclosure volumes for grey slender loris ranged from 5.7 m³ (institute 3) to 94 m³ (institute 1). All study institutions provided data on the number of lorises they house per enclosure; this was found to vary between 1.0-6.0 animals. Fifteen study institutions (75%) house an average of 1.0-2.0 lorises per enclosure. Pygmy slow lorises at six study institutions (9, 10, 11, 14, 15 & 17) are housed in mixed species exhibits, this makes up 30% of total study institutions. The species housed with pygmy slow loris consisted of: *Galago senegalensis* (institute 10) *Hypogeomys* (institute 10), *Nycticebus coucang* (institute 17), *Tolypeutes matacus* (institute 15), *Tupaia belangeri* (institute 11), and *Chevrotains* (institutions 9 &14).

All institutions provided data on floor substrate used in their enclosures (Table 10). Nineteen (95%) of these study institutions were found to supply a floor substrate. Floor substrates used were shredded bark, cocopeat, hay and dried grass, wood shaving, straw, leaf litter, stones, sand and peat. The most common substrate used was shredded bark (75% of study

institutions). Nest boxes were provided within enclosures at nineteen (95%) of the twenty study institutions. One institution (institute 2) did not offer a nest box in their loris enclosure. This institution offered a tube of cork an alternative nesting site. The highest number of nest boxes offered in a single enclosure was three; this number was provided at three different institutions (4, 14 & 20). Ten study institutions (50%) provide one nest box in their loris enclosures.

Questionnaire data found nineteen study institutions (95%) offer round timber branches of different widths within enclosures. The only institution not to offer a variety of these size branches was institute 17. Enclosures at all study institutions consisted of both horizontal and vertical branches and had a climbing structures that provided a continuous pathway around the enclosure (e.g. gaps between the branches are close enough together for the animal to reach without having to jump) and easy access to the ground. Three study institutions (3, 7, & 16) do not have their loris enclosures on show to the public. Five institutions (2, 4, 9, 14, &15) were found to have both on show and off show enclosures that house the species.

A regression test was carried out to investigate whether institution breeding success is dependent on the following variables: volume of enclosure; number of nest boxes within the enclosure. At a 0.05% significance level results found there was no significant correlation (Table 16).

The Kendall rank-order correlation statistical test was carried out to determine if there was a significant correlation between institution breeding success and housing pygmy slow loris in a mixed-species exhibits (Dytham 2003). At a 0.05% significance level results found there was a significant correlation between these two variables (T =0.571, N=11, P=0.037) (Appendix 9b).

Table 10: Enclosure size and furniture of grey slender loris and pygmy slow loris exhibits at 20 European zoos. Mean volume of enclosure (M^3) St.dev = 38.7. Mean total number of lorises per enclosure St.dev = 1.19.

Zoological institution	Species kept	Mean volume of enclosure (M^3)	Mean total number of lorises per enclosure	Housed in a mixed species exhibit	Type of floor substrate	Number of nest boxes per enclosure
1	Grey slender loris	94.0	2.5	No	Shredded bark or cocopeat	1
2	Grey slender loris	10.6	1.3	No	Shredded bark	0
3	Grey slender loris	5.7	2.5	No	Shredded bark, hay and dried grass	1
4	Grey slender loris	12.0	6.0	No	Shredded bark, wood shavings, straw, leaf litter	3
5	Pygmy slow loris	No answer given	1.5	No	shredded bark	2
6	Pygmy slow loris	6.6	2.0	No	shredded bark	2
7	Pygmy slow loris	1.0	2.0	No	None, just the fallen leaves on the cage bottom	1
8	Pygmy slow loris	3.6	2.0	No	Shredded bark	1
9	Pygmy slow loris	28.3	2.0	Yes	Shredded bark, boxes wood chip	2
10	Pygmy slow loris	39.0	4.0	Yes	Leaf litter, stones, french bark	4
11	Pygmy slow loris	40.0	3.0	Yes	Leaf litter, soil mixed with a bit of gravel, sand	2
12	Pygmy slow loris	17.5	1.5	No	Shredded bark, wood shavings	1
13	Pygmy slow loris	6.6	1.0	No	Pine bark	1
14	Pygmy slow loris	29.3	1.3	Yes	Shredded bark, wood shavings, leaf litter	3
15	Pygmy slow loris	6.0	1.7	Yes	Shredded bark, sand , peat	1
16	Pygmy slow loris	3.4	1.0	No	Shredded bark, wood shavings	1
17	Pygmy slow loris	8.2	1.0	Yes	Shredded bark	1
18	Pygmy slow loris	160.0	1.0	No	Shredded bark	2
19	Pygmy slow loris	19.5	2.0	No	Wood shavings	1
20	Pygmy slow loris	25.2	2.0	No	Shredded bark	3

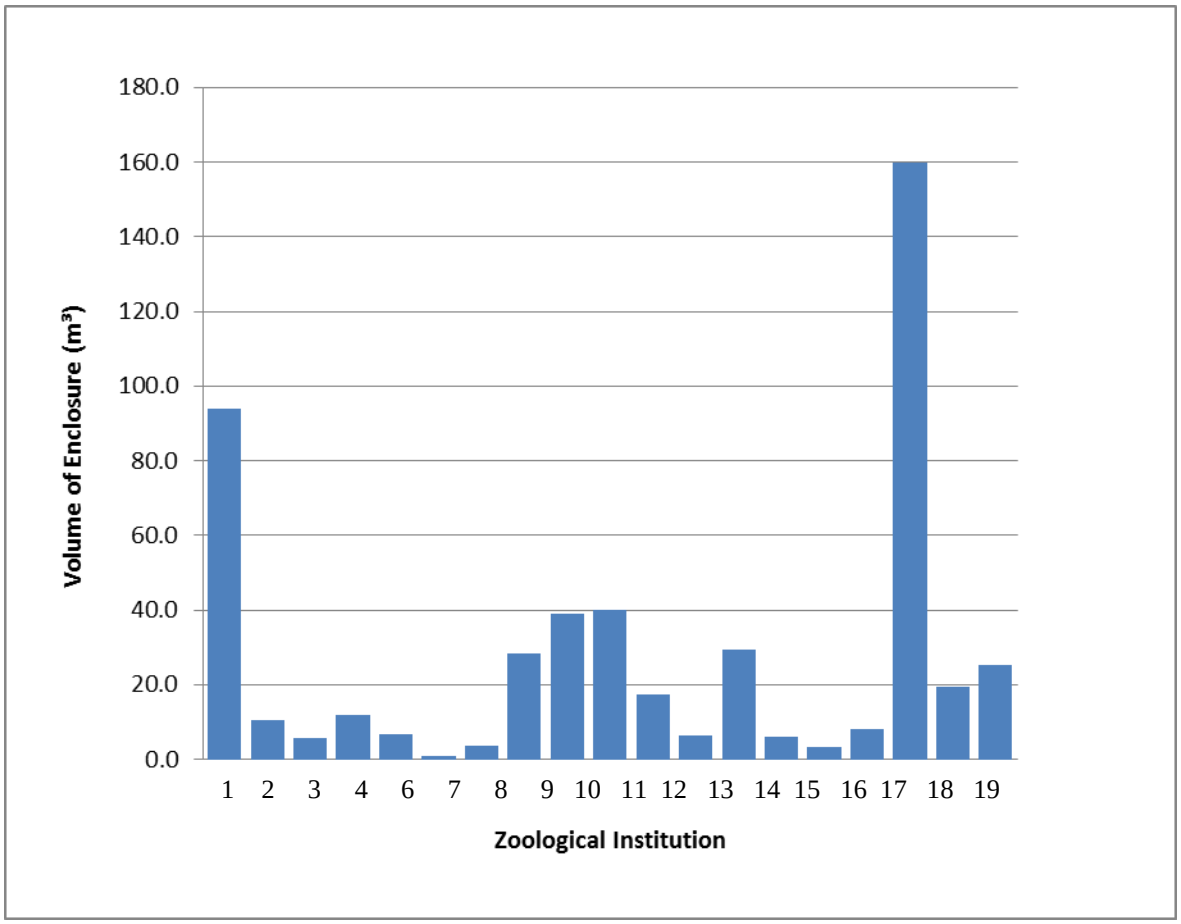

Figure 19: Grey slender loris and pygmy slow loris enclosure volume (m³) at 19 European zoological institutions. This chart highlights the large variance in enclosure volumes.

3.2. Husbandry routines

All study institutions provided data on the husbandry routines they use for lorises at their institutions (Table 11). The number of different zoo keepers that look after these species was found to vary between two (institutions 3 & 5) and eleven (institute 11). One institution (17) reported numerous different keepers look after their captive population. This institution was reliant on volunteers and work placements for carrying out husbandry methods on their population. The most frequent number of different zoo keepers looking after lorises was three; this amount of different keepers was used at six institutions (6, 12, 16, 18, 19 & 20). Approximate number of separate occasions a keeper enters a loris enclosure in one day ranged from 0-4 times (Table 11). One institution (3) reported that they do not usually enter the enclosure while the animals are inside; food and enrichment are provided through the doors of the enclosure. The highest number of times a keeper enters an enclosure in one day was four, this number was reported by one institute (4). The overall approximate mean number of occasions a keeper enters an enclosure in one day was 2.2 ± 0.84 times.

Nineteen institutions provided data on the approximate total amount of time keepers spend within their loris enclosure over a 24 period. This period of time varied between five minutes (institute 2) to 90 minutes (institutions 8 &16). The mean amount of time spent in a loris enclosure for this time period for these nineteen study institutions was 31.2 ± 24.54 minutes. Eighteen institutions provided data on the interval duration between cleaning the fixed enclosure furniture. This ranged from every two days (institute 17) to every 18-24 months (institute 15). One institute (institute 20) cleans this furniture only when the furniture within the enclosure is being changed, this is approximately once every six months. The most common period between cleaning this furniture was monthly, seven institutions (4, 5, 6, 13, 16, 18) clean the fixed furniture in their loris enclosures this number of times. The amounts of time between replacing the floor substrate also varied between institutions. Frequency of changing this substrate ranged between weekly (institute 12) to every 18-24 months (institute 15).

A regression test was carried out to investigate whether institution breeding success is dependent on the following variables: average total duration a keeper is inside the enclosure in one day; number of different keepers looking after the animals. At a 0.05% significance level results found there was no significant correlation (Table 16).

The Kendall rank-order correlation statistical test was carried out on the non-parametric husbandry questionnaire data to determine if there was a correlation between breeding success and the interval duration between cleaning the fixed enclosure furniture (Dytham 2003). At a 0.05% significance level results found a significant positive correlation between these variables (T= 0.491, N=13 , P=0.030) (Figure 20, Appendix 9a) .

At a 0.05% significance level, the Kendall rank-order correlation statistical test found no significant correlation between institution breeding success and the interval duration between replacing the floor substrate (T=0.167, N=13, P=0.451) (Appendix 9c).

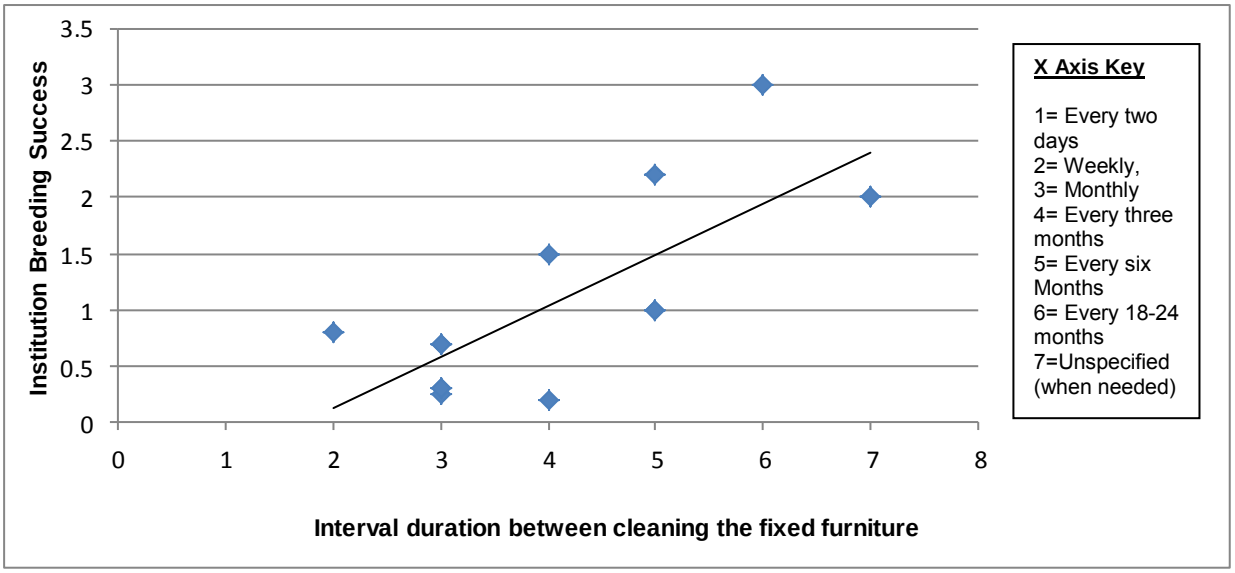

Figure 20: Scatter chart showing the correlation between institution breeding success and the interval duration between cleaning the fixed enclosure furniture at 13 European institutions housing grey slender loris and pygmy slow loris. This chart shows a positive correlation between these two variables.

Table 11: Husbandry routines for grey slender loris and pygmy slow loris at 20 European zoological institutions.

Zoological Institution	Species kept	Number of different keepers	Approx. number of times a keeper enters enclosure in one day	Approx. total duration of time a keeper is present in the enclosure over a 24hr period (Minutes)	Interval duration between cleaning fixed furniture	Interval duration between replacing floor substrate
1	Grey slender loris	7	3	15	Answer not given	Once a year
2	Grey slender loris	10 (approx. 3 per day)	2-3	5	Every 3 months	Every 3 months
3	Grey slender loris	1 (plus 1 cover keeper)	0 - Usually do not enter while lorises are inside (food and enrichment is provided through doors).	0	Irregular (every six months if possible, sometimes longer)	Every few months
4	Grey slender loris	7	4	60	Monthly	Every 6 months
5	Pygmy slow loris	1 (plus 1 cover keeper)	1	15	Monthly	Monthly
6	Pygmy slow loris	3	2	20	Monthly	Once a year
7	Pygmy slow loris	5	2	20	Weekly	N/A - no floor substrate
8	Pygmy slow loris	2	2	30 – 90	When needed	Every 3 months
9	Pygmy slow loris	5	2	No more than 60 minutes	Monthly	Every 3 months
10	Pygmy slow loris	4	3	45	When needed	1-3 times a year
11	Pygmy slow loris	11	2	10	Every 3 months	When needed
12	Pygmy slow loris	3	3	30	Every 6 months	Weekly
13	Pygmy slow loris	2-3	3	15-30	Monthly	No answer given
14	Pygmy slow loris	5	2	30-45	Answer not given	When needed
15	Pygmy slow loris	4	1	20	Every 18 - 24 months	Every 18 - 24 months
16	Pygmy slow loris	3	3	90	Monthly	No answer given
17	Pygmy slow loris	Numerous (rely on volunteer & work placements)	3	20-30	Every 2 days (as part of regular cleaning routine)	Every few months
18	Pygmy slow loris	3	3	30	Monthly	Every 3 months
19	Pygmy slow loris	3	1	15	Every 3 months	Once a year
20	Pygmy slow loris	3	2	10 -15	Only when furniture is changed (approx. every 6 months)	Every 2 months

3.3 Environmental conditions inside enclosures

Thirteen institutions (85% of all study institutions) use a reverse light in their loris exhibits (Table 12). The total amount of time in a 24 hours period that an enclosure was in daylight/darkness was reported by eighteen study institutions. Two other study institutions (3 & 17) reported that their enclosures use the natural day length. The mean amount of daylight provided at study institutions varied between 10.5 hours (institute 9) to 14 hours (institute 5). The mean amount of daylight hours was calculated at 12.1 ± 0.80 hours over a 24 hour period. Average hours of darkness provided in loris enclosures at 18 institutions ranged between from 10 hours (institute 5) to 13.5 hours (institute 9). The mean total amount of time an enclosure was in darkness was 11.9 ± 0.80 hours over a 24 hours period. Light levels at 10 (50%) study institutions vary throughout the year to simulate the changes in season. Nineteen study institutions provided an answer as to whether their lorises have access to outdoors. The results found two study institutions (7 & 14) offer outdoor access to their animals.

Seventeen study institutions supplied measurements for their internal enclosure temperature, this varied between 18°C - 30°C. The mean enclosure temperature for grey slender loris enclosures was 23.7 ± 7.64°C; pygmy slow loris enclosures mean = 23.3 ± 13.80°C. Ten institutions (50% of study institutions) vary the temperatures within their enclosures throughout the year to simulate the changes in season.

Fourteen study institutions provided measurements of relative humidity (RH) within their enclosures, these measurements range from 30%-85%. The mean RH level for grey slender loris enclosures was found to be 66.7 ± 0.70% and pygmy slow loris enclosure had a mean RH level of 66.4 ± 4.95%. Four study institutions (15, 17, 19 & 20) do no measure RH levels within their loris enclosures. Three study institutions (1, 9 & 12) vary their RH levels throughout the year to simulate the changes in season (15% of study institutions).

A regression test was carried out to investigate whether institution breeding success is dependent the following environmental conditions: average hours of daylight/darkness over a 24 hour period; average enclosure temperature; average relative humidity of enclosure. At a 0.05% significance level results found no significant correlation (Table 16).

The Kendall rank-order correlation statistical test was carried out on the non-parametric husbandry questionnaire data to determine if there was a correlation between breeding

success and the following variables: Reverse light cycle used; light level varied throughout the year and temperature varied throughout the year (Dytham 2003). At a 0.05% significance level results found no correlation between these variables (Table 17).

Table 12: Environmental conditions within grey slender loris and pygmy slow loris enclosures at 20 European zoological institutions. Mean hours of daylight St.dev = 0.80. Mean hours of daylight St.dev = 0.80.

Zoological institution	Species kept	Reverse light cycle used	Mean hours of daylight	Mean hours of darkness	Light levels vary throughout the year	Access to outdoors	Enclosure temperature (°C)	Temperature varies throughout the year	Enclosure relative humidity level (%)	Humidity levels vary throughout the year
1	Grey slender loris	Yes	12	12	No	No	22-25	Yes	40-80	Yes
2	Grey slender loris	Yes	12	12	Yes	No	No answer given	No	No answer given	No
3	Grey slender loris	No	Natural day length		Yes	No answer given	No answer given	Yes	70-80	No
4	Grey slender loris	Yes	12	12	No	No	22-26	Yes	55-75	No
5	Pygmy slow loris	Yes	14	10	No	No	No answer given	No	No answer given	No
6	Pygmy slow loris	Yes	12	12	No	No	22	No	65	No
7	Pygmy slow loris	No	12	12	Yes	Yes	25 (average)	Yes	60-70	No
8	Pygmy slow loris	Yes	12.5	11.5	Yes	No	26-30	Yes	80	No
9	Pygmy slow loris	Yes	10.5	13.5	No	No	18-24	Yes	45-55	Yes
10	Pygmy slow loris	Yes	12	12	No	No	24-27	No	60-80	No
11	Pygmy slow loris	No	11	13	No	No	20-25	No	~80	No
12	Pygmy slow loris	Yes	11.5	12.5	Yes	No	20-23	No	70-80	Yes
13	Pygmy slow loris	Yes	12	12	No	No	23-25	No	30-40	No
14	Pygmy slow loris	No	13	11	Yes	Yes	22-26	Yes	60-70	No
15	Pygmy slow loris	Yes	12.3	11.7	Yes	No	~23	No	Not measured	No
16	Pygmy slow loris	No	12	12	No	No	23-25	No	60-70	No
17	Pygmy slow loris	No	Natural day length		No	No	18-19	Yes	Not measured	No
18	Pygmy slow loris	Yes	12	12	Yes	No	29	No	75-85	No
19	Pygmy slow loris	No	12	12	Yes	No	20-25	Yes	Not measured	No
20	Pygmy slow loris	Yes	13.5	10.5	Yes	No	18-21	Yes	Not measured	No

3.4 Captive diet

Nineteen study institutions supplied information on the content of the diet they fed their captive lorises. Results of this data found all these study institutions offer a variety of fresh fruit as part of the animal's captive diet (Table 13). Eighteen of these institutions (95%) also provide a variety of either fresh or cooked vegetables. One institution (7) offers one type of vegetable to their animals (cucumber). Nine institutions were found to offer a dry primate pellet food as part of the animals' captive diet (47.4% of study institutions). One of these study institutions (4) also supplied cat food to their animals. Sixteen institutions offer insects as part of their captive loris diet (84.2% of study institutions). Other food types that were offered at various institutions included: boiled egg, baby cereal/porridge and Marmoset Jelly. Two institutions (9 & 14) include gum as part of their animal's regular diet. Institution 9 offer gum four times a week and institution 14 offer this food item three times a week.

All study institutions provided data on the feeding methods used (Table 14). Results found: eleven institutions (55% of all study institutes) feed their animals once a day; six institutions (30% of study institutes) provide two feeds a day and three institutions (15% of study institutes) provide three feeds a day. Four study institutions were found to vary the time they feed their animals' each day (institutions 1, 9, 10 & 20), with 80% (15 study institutions) feeding their animals at the same each day. 'In a bowl' was found to be the most common method of presented the food with eleven institutions using this method (Table 11). A mix of two food presentation methods was found to be used at five institutions (3, 14, 15, 18 & 19). Three institutions (4, 9 & 11) use the single method of scattering food around the enclosure. One institute (1) uses the single presentation method of hanging half coconuts shells of food. Eleven of the twenty study institutions offered a gum-based enrichment to their animals. An additional institution has just recently started offering this type of enrichment (institute 17).

A regression test was carried out to investigate whether institution breeding success is dependent number of feeds a day. At a 0.05% significance level results found there was no significant linear relationship (Table 16).

The Kendall rank-order correlation statistical test was carried out on the non-parametric husbandry questionnaire data to determine if there was a correlation between breeding success and the following two variables: presentation method of food; Provision of gum-enrichment (Dytham 2003). At a 0.05% significance level, the Kendall rank-order correlation statistical test found no significant correlation between these variables (Table 17).

Table 13: Contents of captive diet fed to grey sender lorises and pygmy slow lorises at 19 European zoological institutions.

Zoological institution	Species kept	Food items offered						Diet varied according to the season
		Variety of fresh fruit	Variety of fresh/cooked vegetables	Dry primate pellets	Insects	Vitamin/mineral supplements	Other	
1	Grey slender loris	X	X		X	X	Milk pudding (made of milk powder, flour, water), egg yolk, Inulin (dietary fibre supplement), wheat bran.	No
2	Grey slender loris	X	X		X	X	Bezo-pet (supplement to help maintain a healthy digestive tract), egg, heart meat.	No
3	Grey slender loris	X	X	X	X	X	Milk formula, wheat bran, Inulin (dietary fibre supplement).	Yes
4	Grey slender loris	X	X	X			Honey, cat food.	Yes
5	Pygmy slow loris	X	X	X	X		Boiled egg white, day old chick.	No
6	Pygmy slow loris	X	X		X		Baby cereals	No
7	Pygmy slow loris	X	1 x vegetable offered (cucumber)	X			Baby cereal, boiled egg, rice with olive oil.	No
8	Pygmy slow loris	X	X		X		Marmoset Jelly (supplementary feed high in energy and protein), oat cakes, cottage cheese, cheese, egg, boiled chicken and rice.	Yes
9	Pygmy slow loris	X	X	X	X		Boiled egg, gum arabic.	No
10	Pygmy slow loris	X	X		X		Mazuri Tamarin Cake (supplementary feed high in essential vitamins and minerals).	No
11	Pygmy slow loris	X	X		X			Yes
12	Pygmy slow loris	X	X		X		Various nuts and seeds, raisins, yogurt, honey, rabbit, chicken, porridge, boiled egg.	Yes
13	Pygmy slow loris	X	X	X	X		Egg, cooked rice, cooked beef, natural yogurt, wheat shoots.	Yes
14	Pygmy slow loris	X	X	X	X		Egg, gum.	No
15	Pygmy slow loris	X	X		X		Chicken	Yes
16	Pygmy slow loris	X	X	X	X		Boiled meat.	No
17	Pygmy slow loris	X	X	X			Baby cereal/porridge, Marmoset Jelly (supplementary feed high in energy and protein) mixed with Marex.	No
18	Pygmy slow loris	X	X		X		Baby mouse (pinky), Marmoset Jelly (supplementary feed high in energy and protein), egg, gum.	No
20	Pygmy slow loris	X	X		X		Powder for Callitrichids.	No

Table 14: Captive feeding methods used for populations of grey slender loris and pygmy slow loris at 20 European zoological institutions.

Zoological institution	Species kept	Number of feeds per day	Fed at the same time each day	Presentation of food	Is gum-based enrichment provided?
1	Grey slender loris	2	No	Coconut shells cut in half hanging on branch	No
2	Grey slender loris	2	Yes	In a bowl	Yes
3	Grey slender loris	2	Yes	In a bowl & scattered around enclosure	No
4	Grey slender loris	3	Yes	Scattered around enclosure	Yes
5	Pygmy slow loris	1	Yes	In a bowl	Yes
6	Pygmy slow loris	2	Yes	In a bowl	No
7	Pygmy slow loris	1	Yes	In a bowl	Yes
8	Pygmy slow loris	3	Yes	In a bowl	Yes
9	Pygmy slow loris	2	No	Scattered around enclosure	Yes
10	Pygmy slow loris	3	No	In a bowl	No
11	Pygmy slow loris	2	Yes	Scattered around enclosure	No
12	Pygmy slow loris	1	Yes	In a bowl	Yes
13	Pygmy slow loris	1	Yes	In a bowl	No
14	Pygmy slow loris	1	Yes	In a bowl & scattered around enclosure	Yes
15	Pygmy slow loris	1	Yes	In a bowl & scattered around enclosure	Yes
16	Pygmy slow loris	1	Yes	In a bowl	No
17	Pygmy slow loris	1	Yes	In a bowl	No - not previously but recently started
18	Pygmy slow loris	1	Yes	Scattered around enclosure and hidden in half coconuts	Yes
19	Pygmy slow loris	1	Yes	In a bowl & scattered around enclosure	Yes
20	Pygmy slow loris	1	No	In a bowl	No

3.5 Captive breeding

Fifteen institutions provided information on breeding lorises at their establishment (Table 15). Fourteen of these institutions are currently breeding their captive lorises and one institution (14) bred pygmy slow lorises until the year 2009. From this total: four institutions (1, 2, 3 & 4) breed grey slender loris and eleven institutions breed/use to breed pygmy slow loris (Table 15). The breeding success of each institution was calculated (Table 15, Figure 21) (see Part 2, Chapter 2.0 for breeding success formula and period of analysis). Results of these calculations found study institution 15 to have the highest breeding success (3.0). Study institution 1 was found to have the lowest breeding success (0.7).

Twelve study institutions (86% of the fourteen study institutions currently breeding the species) reported that they house compatible breeding animals together permanently. Two study institutions (2 & 10) house their breeding animals separately and only mix compatible animals for breeding.

Table 15: Breeding population and institution breeding success of grey slender loris and pygmy slow loris at 15 European zoological institutions.

Zoological Institution	Species kept	Institution breeding success*	Current number of breeding males	Current number of breeding females	Compatible breeding animals housed together permanently
1	Grey slender loris	0.7	2	2	Yes
2	Grey slender loris	1.5	2	2	No - only mixed for breeding
3	Grey slender loris	2.2	2	3	Yes
4	Grey slender loris	0.7	1	2	Yes
5	Pygmy slow loris	0.25	1	1	Yes
7	Pygmy slow loris	0.8	1	1	Yes
9	Pygmy slow loris	0.7			Yes
10	Pygmy slow loris	2.0	1	3	No - only mixed for breeding
12	Pygmy slow loris	1.0	1	1	Yes
14°	Pygmy slow loris	1.5	N/A	N/A	N/A
15	Pygmy slow loris	3.0	2	2	Yes
16	Pygmy slow loris	0.3	2	2	Yes
18	Pygmy slow loris	0.3	1	0 (female died in 2012, actively looking for another)	Yes (until death of female)
19	Pygmy slow loris	0.2	1	1	Yes
20	Pygmy slow loris	1.0	1	1	Yes

* Total number of live births/number of years that female animals (over 2 years) were kept at the institution (from 1st January 1990 to 31st December 2012).
° Institution actively bred animals until 2009

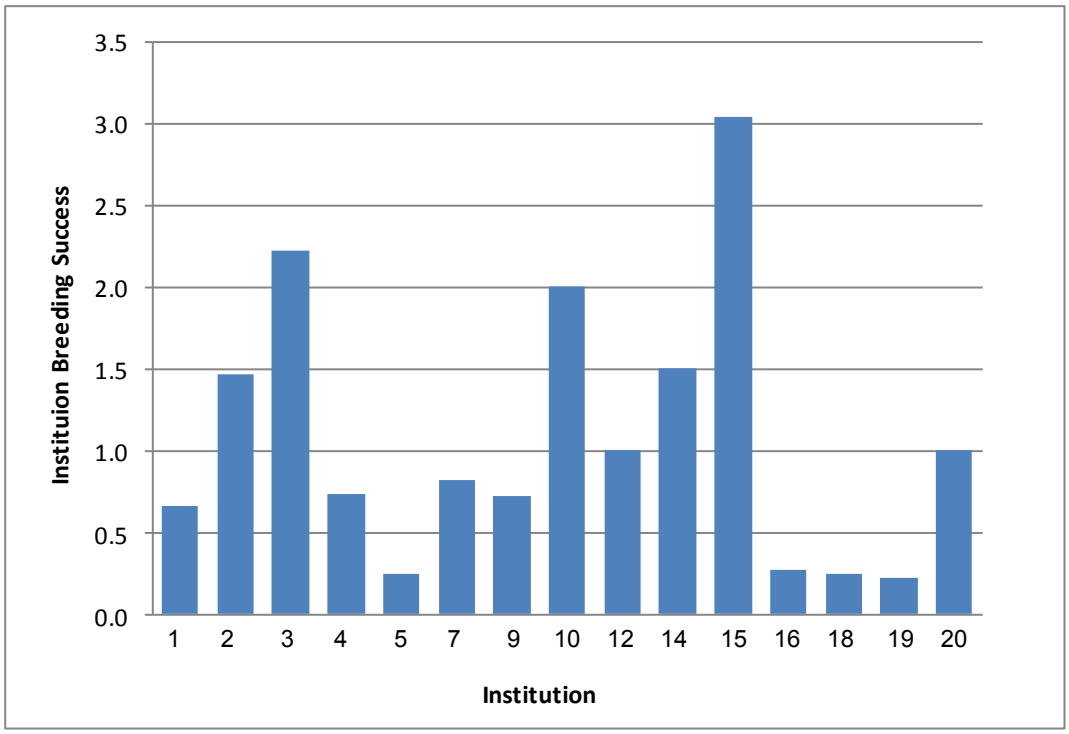

Figure 21: Institution breeding success of grey slender loris and pygmy slow loris at 15 European zoological institutions. The chart highlights the highest breeding success occurred at institution 15.

Table 16: Results of regression tests carried out to determine if institution breeding success depends on husbandry methods used at 15 European zoological institutions housing grey slender loris and pygmy slow loris.

Husbandry variable tested	**Statistical Result (significance level 0.05%)**
Number of feeds a day	F = 0.674, P = 0.427 (Appendix 8a)
Volume of enclosure	F = 1.504, P = 0.244 (Appendix 8b)
Number of nest boxes within the enclosure	F = 0.008, P = 0.931 (Appendix 8c)
Average hours of daylight over a 24 hour period	F =0.001, P = 0.981 (Appendix 8d)
Average hours of darkness over a 24 hour period	F =0.001, P =0.981 (Appendix 8e)
Average enclosure temperature	F = 0.075, P = 0.790 (Appendix 8f)
Average relative humidity of enclosure	F =0.473, P = 0.511 (Appendix 8g)
Average total duration of time a keeper is inside the enclosure in one day	F = 1.168, P =0.299 (Appendix 8h)
Number of different keepers looking after the animals	F = 0.086, P =0.774 (Appendix 8i)

Table 17: Results of Kendall rank-order correlation statistical tests carried out to determine if institution breeding success correlates with husbandry methods used at 15 European zoological institutions housing grey slender loris and pygmy slow loris.

Husbandry variable tested	**Statistical Result (significance level 0.05%)**
Presentation method of food	T = -0.012, N=15, P=0.957 (Appendix 9d)
Provision of gum-enrichment	T= -0.171, N=15, P=0.460 (Appendix 9e)
Reverse light cycle used	T=0.057, N=15 , P=0.805 (Appendix 9f)
Light levels varied throughout the year	T=0.315, N=15, P=0.173 (Appendix 9g)
Temperature varied throughout the year	T=-0.054, N=15, P=0.816 (Appendix 9h)

Part 2

Chapter Four

4.0 Discussion

This part of the study specifically focussed on the European captive populations of grey slender loris and pygmy slow loris. The study looked into the husbandry methods used within European zoos for this species and investigated if breeding success depended on the type of method used. Questionnaires were sent to all known EAZA accredited European zoos that house these species. Thirty zoos were contacted, of which twenty zoos returned a completed questionnaires (four institutions housing grey slender loris, 16 holding pygmy slow loris). Two additional zoos no longer kept the species at their establishment and were therefore unable to complete a questionnaire.

Fifteen of the total twenty study institutions provided data on breeding the species at their establishment (Table 15). The breeding success for these zoos was calculated. Data collected from the survey were statistically analysed to determine if there was a relationship between husbandry parameters and breeding success. Results from these analyses along with husbandry data collected from all study zoos are discussed within this chapter.

4.1. Enclosure area and furniture

Results from this study found the mean enclosure volume to vary greatly (1m³-160m³) (Figure 19, Table 10). A husbandry survey carried out on 29 North American zoological establishments also found great variation within enclosure size for lorisid primates (Fuller *et al* 2012). Within this current study just over half of European institutions were found to keep their animals in enclosures that were smaller than the recommended cage size of 15.6m³ (Table 10) (Fitch-Snyder and Schulze 2001). Fitch-Snyder and Schulze (2001) stress that the guideline on enclosure size is the minimum area captive lorises should be housed in and is not considered an optimal size for these animals.

Results found seven of a total of fifteen study institutions housing pygmy slow loris kept their animals in enclosures smaller that the recommended minimum size (Table 10). The average volume of pygmy slow loris enclosures varied between 1.0m³ -160m³ (Figure 19, Table 10). Grey slender loris were housed in enclosure volumes ranging from an average of 5.7 m³ to 94 m³ (Table 10), with three of a total of four establishments keeping their animals in an

enclosure space lower than the recommended guidelines (Table 10). Daschbach *et al* (1982/83) found activity levels in slow loris decreased when housed in smaller enclosures. Fuller *et al* (2012) discovered pygmy slow lorises in North American institutions were generally kept in enclosures meeting the requirements of husbandry guidelines; however slender lorises were kept in enclosures smaller than recommended (Fuller *et al* 2012). Therefore results on European grey slender loris enclosures discovered similar results to Fuller *et al* (2012).

Findings from this research showed EAZA accredited zoos generally follow recommended guidelines in regard to habitat design for captive lorises (Fitch-Snyder and Schulze 2001).
The furniture within all grey slender and pygmy slow loris enclosures provide animals with a continuous pathway, allowing them to utilize all of the enclosed area (Chapter 3.0, Section 3.1). The furniture supplied in all European study institutions included horizontal and vertical branches. The vast majority of study institutions reported to vary the width of branches within their enclosures (Chapter 3.0, Section 3.1). Research published since husbandry guidelines were produced found Bengal slow loris to regularly use small and medium upward sloping branches and were often seen in open areas of dense grassland. (Rogers and Nekaris 2011). Red slender lorises were found to use substrates with a circumference of less than 5cm² (Nekaris 2005).

The majority of European zoos were found to provide at least one nest box within their loris enclosure (Table 10). Fuller *et al* (2012) found similar results in North American zoo and related institutions, with each animal having a hiding spot/sleeping site within their enclosure. Guidelines recommend lorises should be provided with several sleep sites within their captive environment (Fitch-Snyder and Schulze 2001). Statistical test to determine if institution breeding success depends on the number of nest boxes per enclosure found no significant correlation between these two variables (Table 16). Results from this statistical test therefore suggest that the number of nest boxes did not impact on breeding success of the species. However, data on different types of sleep sites provided within the enclosures were not collected within this study and therefore were unable to be included in this analysis. Collecting data on all types of sleep sites provided would allow for a more in-depth analysis to take place.

4.2. Husbandry routines

Results from this current study found a significant positive correlation between institution breeding success and the interval duration between cleaning the fixed enclosure furniture within loris enclosures (Chapter Three, Section 3.7). These results found institutions that leave greater lengths of time between cleaning enclosure furniture have higher institution breeding success than institutions that clean more frequently. The European zoo (institute 15) that were calculated as having the highest breeding success of all participating institutions were also found to leave the longest period of time between cleaning this furniture (18-24 months) (Table 11 & 15). The lengths of time between replacing enclosure floor substrate were also statistically analysed. No significant correlation was found between institution breeding success and the interval duration between replacing the floor substrate. This result indicated that the length of time left between replacing the floor substrate does not affect breeding success.

Fuller *et al* (2012) suggest intensive cleaning methods could interfere with chemosensory signals in captive lorisids and stresses that the effects of cleaning on olfactory communication needs to be critically evaluated. Schilling (1979) cited by Lewis (2005) found scent marking to be common in prosimians. Fisher *et al* (2003a) later discovered that the reproductive behaviour of female pygmy slow loris is governed by chemosensory signals. Similar results were also found in studies carried on other prosimian species. Lewis (2005) looked at scent marking in Verreaux's Safika (*Propithecus verreauxi verreauxi*) and suggested it is a crucial aspect in the species intrasexual relationships. Palagi *et al* (2005) conducted a study on the marking functions of urine in ring-tailed lemurs (*Lemur catta*) and proposed it may play a role in intra-group reproductive communication. Fuller *et al* (2012) suggest institutions breeding lorisids should pay careful consideration in addressing olfactory requirements within the captive environments they provide their animals. Results from this current study supports Fuller *et al* (2012) as the positive correlation discovered between institution breeding success and the interval duration between cleaning the fixed enclosure furniture provide a strong indication that this husbandry method does interfere with chemosensory signals in lorises. Reducing the frequency with which loris enclosures are cleaned could therefore potentially increase the breeding success of captive lorises.

Husbandry guidelines written twelve years ago recommend enclosures should not be cleaned frequently to limit stress to the animals (Fitch-Snyder and Schulze 2001). It is recommended that branches within enclosures are cleaned every few weeks to remove any

build-up of urine to avoid potential health problems to the animals (Fitch-Snyder and Schulze 2001). Results from the questionnaires found the interval duration between cleaning the fixed enclosure furniture in European zoos greatly varied between every two days to every 18-24 months (Table 13). The most common period between cleaning the fixed furniture was monthly (Table 11). Although Fuller *et al* (2012) included a question within their questionnaire on the regularity of cleaning enclosures, the survey did not differentiate between the different types of cleaning methods that were carried out (e.g. spot cleans, intensive cleaning), it was therefore not possible to compare results gained from European zoos to the frequency of cleaning routines in North American establishments.

4.3. Environmental conditions inside the enclosure

A number of environmental conditions within loris enclosures were tested. Results from statistical analyses found no significant correlation between institution breeding success and the following environmental variables: temperature level; relative humidity (RH); hours of daylight/darkness; and the use of a reverse light cycle (Chapter Three, Section 3.7). These results indicate breeding success is not dependent on environmental conditions within enclosures.

Zoos that provided data on the temperature of their loris enclosures all used a range that fell within the recommended husbandry guidelines of 65.5°F – 85.5°F (18.6°C - 29.7°C) (Table 12) (Fitch-Snyder and Schulze 2001). Both grey slender and pygmy slow loris enclosures were found to be kept at very similar mean temperatures (grey slender loris enclosures = 23.7°C; pygmy slow loris enclosures = 23.3°C). Fuller *et al* (2012) also found North American institutions follow husbandry guidelines in regard to enclosure temperature.

Half of all study institutions were found to vary enclosure temperature throughout the year (Chapter Three, Section 3.3). Published research discovered changes in temperature cause variations in the activity levels of pygmy slow loris. Evans *et al* (2000) cited by Starr *et al* (2012) carried out study on wild pygmy slow loris in Laos. They observed fewer sightings of the species in the colder months, which suggest their activity levels decrease at this time. A study on captive pygmy slow loris discovered the species to exhibit long periods of inactivity during colder temperatures (Streicher 2004 cited by Starr *et al* 2012). Starr *et al* (2012) investigated the effects of temperature and moonlight on activity levels in wild pygmy slow

loris. They found the animals were more active on bright warm temperatures and less active on cold bright nights.

RH levels within loris enclosures were found to generally not fall within the recommended guidelines (Table 12) (Fitch-Snyder and Schulze 2001). Only two study institutions followed the recommended RH level of 40%-60% (Table 12) (Fitch-Snyder and Schulze 2001). The mean RH level for grey slender loris enclosures was found to be 66.7%, and pygmy slow loris enclosure had a mean RH level of 66.4%. Compared to RH levels of loris enclosures in North American zoological institutions these results were found to differ (Fuller *et al* 2012). Fuller *et al* (2012) found the RH level Mean RH for both slender loris and pygmy slow loris met the requirements of husbandry guidelines (Fitch-Snyder and Schulze 2001). Petter (1975) and Glatson (1981) as cited by Debyser (1995) highlighted humidity as an important factor in allowing prosimians to carry out species-specific sexual and mothering behaviours.

4.4 Mixed-species exhibits

A statistical test was carried out on the study institutions housing pygmy slow loris to determine if there was a correlation between breeding success and mixed-species exhibits. This test found a significant correlation between these two variables (Chapter Three, Section 3.6). This significant result indicates institutions that house this species with a different species have a higher institution breeding success than institutions that house the species as a single-species exhibit. *Chevrotains, Galago senegalensis*, *Hypogeomys* and *Tolypeutes matacus* were all species reported to share enclosures with pygmy slow loris in European zoos. Although a significant result was identified, I consider this result as suggestive rather than conclusive due to the small sample size (11 study institutions), and non-parametric statistical tests being less powerful than tests developed for data with a normal distribution (Dytham 2003, Hawkins 2009). In order to confirm this significant result further investigation is required (Dytham 2003, Hawkins 2009).

Leonardi *et al* (2010) and Dalton & Buchanan-Smith (2005) found mixed-species primate exhibits to be successful. Leonardi *et al* (2010) discovered mixed species groups of captive capuchin (*Cebus apella*) and squirrel monkeys (*Saimiri sciureus*) to successfully co-exist in the same enclosure space. Goeldi's monkeys (*Callimico goeldii)* and pygmy marmosets (*Callitrix pygmaea*) were also found to successfully share the same captive environment (Dalton & Buchanan-Smith 2005).

Mixed-species exhibit are considered to have many benefits (Fitch-Snyder and Schulze 2001, Veasey and Hammer 2010). Leonardi *et al* (2010) suggest their capuchin and squirrel monkeys mixed exhibit provide behavioural enrichment for both species. Fitch-Snyder and Schulze (2001) and Veasey and Hammer (2010) also mention behavioural enrichment as a benefit of these types of exhibits. Other benefits include increased educational opportunities for the public and an effective use of enclosure space (Fitch-Snyder and Schulze 2001, Veasey and Hammer 2010).

Although mixed-species exhibits have many benefits, in order to successfully mix species within a captive environment requires good planning and a well-designed enclosure (Fitch-Snyder and Schulze 2001, Leonardi *et al* 2010, Veasey and Hammer 2010). Mixing species within the same enclosure space can cause stress, aggression and health problems to the animals concerned (Veasey and Hammer 2010). Prior to zoo managers carrying out this exhibit method an objective cost-benefit analysis on the proposed exhibit should take place (Veasey and Hammer 2010). Leonardi *et al* (2010) suggest that primates that naturally associate with each other in the wild are able to co-inhibit in captivity successfully as long as the enclosure is large in size and has been carefully designed. However, great care should be taken before mixing captive lorises with other species until further research has taken place to determine which species they can safely associate with.

4.5. Captive diet

Nineteen study institutions provided captive diet information on their lorises (Table 13). All institutions provided a variety of fruits to their animals and the vast majority also gave a range of different vegetables (Table 13). These items are defined as ‘produce’ in the husbandry guidelines (Fitch-Snyder and Schulze 2001). Husbandry guidelines for lorises include recommendations for captive diet pygmy slow loris (Fitch-Snyder and Schulze 2001). Within these guidelines ‘produce’ should make up 50% of the animal’s captive diet. Fitch-Snyder and Schulze (2001) recommend that 60% of the dry matter requirement in a pygmy slow loris diet should be made up of ‘complete food’ (dry primate pellet and canned food). This current study found 47.4% of study institutions provided ‘complete food’ to their animals (Part 2, Chapter 3.0, Section 3.4).

The majority of zoos gave their animals insects as part of their regular diet (Part 2, Chapter 3.0, Section 3.4); Fitch-Snyder and Schulze (2001) suggest that this food type should make up 5% of a pygmy slow loris diet. Published research that was carried out after the publication of these guidelines discovered wild Mysore slender loris to be almost exclusively faunivorious (Nekaris and Rasmussen 2003). Wiens *et al* (2006) found arthropods made up one of five main food types for wild slow loris. Fitch-Snyder and Schulze (2001) stress that their recommendations only provide basic maintenance for the species and do not fulfil their optimal nutritional requirements. More nutritional research is greatly needed to determine the ideal nutritional requirements for captive lorises (Fitch-Snyder and Schulze 2001). Hume (1995) cited by Schwitzer and Kaumanns (2009) suggest reproductive rate in natural animals populations is mainly controlled by nutrition. Further research to determine nutritional requirements for lorises could therefore potentially lead to increased breeding success for this species in the future.

Results found 80% of European zoos feed their grey slender and pygmy slow lorises at the same time each day (Table 14). The pattern of feeding captive animals at the same time has been found to promote pre-feeding anticipation (PFA) (Hosey *et al* 2009). PFA is found to be a key factor that contributes to the development of stereotypic behaviour in captive animals (Hosey *et al* 2009).

Since husbandry guidelines were published in 2001 (Fitch-Snyder and Schulze 2001), further research focusing on the use of gum by pygmy slow loris found the species to be an obligate exudativory primate (Starr and Nekaris 2013). To allow gummivores to perform this specialist natural behaviour in the captive environment they need to be provided with gum-based enrichments (Huber and Lewis 2011). In this study only two institutions were found to feed gum to their captive pygmy slow loris as part of their regular diet (Table 13). Eleven study institutions were found to provide gum as an environmental enrichment to their captive loris population (Table 14). Nekaris *et al* (2010) suggested that captive environments should allow lorises to carry out gouging behaviours in order to prevent periodontal diseases.

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4.6 Limitations

A known limitation to this part of the study was the small sample size of 20 European zoos (four institutions housing grey slender loris, 16 holding pygmy slow loris). Although this sample size was small, this number of institutions made up 66.7% of all known EAZA

accredited European zoos that hold these species (Chapter Two). An additional two institutions that were contacted as part of this study reported to no longer keep the species, one of which housed grey slender loris. In Part 1 a total of five European zoos were found to hold this species (Table 4), therefore the collected questionnaire data consisted of 100% of all known European institutions currently housing grey slender loris.

European studbook data collected in Part 1 (Chapter 3.0) was required in order to calculate individual institution breeding success. As discussed in Part 1 (Chapter 5.0) this data consisted of a number of known limitations. Population data required for these calculations included the total number of live births (Chapter Two). The studbook data used included some captive born individuals with no known birth dates; these individuals were unable to be included in the analysis. Studbook data also included some individuals with an approximate birth date; this estimated data was included within the analysis.

In order to determine the number for years a study institute has been housing mature female lorises (over 2 years old) the studbook data collected in Part 1 was reviewed. As previously mentioned this data included individuals with an unknown birth date/start date in captivity. Due to this data being incomplete it was not possible to include these individuals within this calculation. The number of years a zoo has been housing the study species was calculated using the earliest recorded date at the study institution. This date was therefore not necessarily the actual first year individuals of this age were at the study institutions, for example some of these individuals may have been housed at the institution for longer than this period.

Captive diet data provided by the study institutions was highly variable. Therefore a statistical analysis on this data was unable to take place. Reported contents of captive diets have been displayed as a list within the results.

Although data used in this study had a number of known limitations, no published research on the institution breeding success of grey slender and pygmy slow loris in European zoos could be found. Studies focussing specifically on how husbandry methods affect the breeding success of these species were also not found in mainstream literature. Therefore carrying out a detailed study on these areas greatly contributes to the limited knowledge of these subject areas.

4.7 Future Work

This study focused on data from zoological institutions within Europe. Carrying out further research using international institutions would provide a fuller picture of the relationship between institution breeding success and husbandry methods.

This current research found a significant positive correlation between institution breeding success and the interval duration between cleaning the fixed enclosure furniture. This study provides preliminary findings in this subject area. Further research should take place to determine the optimal frequency that loris enclosures should be cleaned in order to prevent interference to breeding success. The author also recommends the relationship between infection levels and the interval duration between cleaning the enclosure should be investigated. Part 1 of this research found infection to be the highest reported cause of death in captive nocturnal prosimians. If the interval duration between cleaning the enclosures are increased too much this could lead to higher infection levels.

As discussed in section 4.4 this study suggests a significant correlation between breeding success and mixed-species exhibits at European institutions housing pygmy slow loris. In order to confirm whether these variables are significantly correlated the relationship between these variables requires further investigation. As discussed in Part 1 (Chapter Five) the European captive populations of these study species are not considered to be demographically self-sustaining. Further research to provide confirmation of this correlation is therefore considered extremely important as the results could potentially lead to an increase in breeding success for the species increasing the sustainability of these species in captivity.

Part 2

Chapter Five

5.0 Conclusions

This study looked into the husbandry methods used within European zoos for grey slender and pygmy slow loris. This research investigated if breeding success of these species depended on the husbandry routines used. Husbandry data on these institutions were collected in the form of a questionnaire. Twenty EAZA accredited zoological institutions participated in this research.

The results from this study found institutions used a wide variety of different enclosure sizes to house their animals. Half of all institutions were found not to follow husbandry guidelines, housing their animals in enclosures smaller than the recommended minimum size (Chapter Four, Section 4.1). Grey slender lorises were generally housed in enclosures smaller than recommended; this result was also found in a study of North American institutions (Fuller *et al* 2012). Although husbandry guidelines on enclosure size were generally not followed by many European institutions, this study did find they were followed in regard to habitat design. All zoos supplied horizontal and vertical branches in their enclosures and furniture provided the animals with a continuous pathway around the whole enclosure space. The majority of zoos varied the widths of the branches supplied and supplied at least one nest box (Chapter Four, Section 4.1).

Results from this study indicate cleaning methods interfere with chemosensory signals in lorises. Chemosensory signals in pygmy slow loris have been found to govern reproductive behaviour in female pygmy slow loris (Fisher *et al* 2003a). This research found a significant positive correlation between institution breeding success and the interval duration between cleaning the fixed enclosure furniture within loris enclosures (Figure 21, Section 3.6). The results discovered the longer lengths of time between cleaning the fixed furniture the higher the breeding success. The author suggests that reducing the interval duration that enclosures are deep cleaned could potentially increase the future breeding success of captive lorises.

No relationship was identified between institution breeding success and environmental conditions within loris enclosures (temperature level; relative humidity (RH), hours of daylight/darkness; reverse light cycle) (Table 16 & 17). All reported enclosure temperature levels were found to follow husbandry guidelines (Chapter Four, Section 4.3, Table 12).

However, in general RH levels provided within loris enclosures did not fall within the recommended levels (Chapter 4.0, Section 4.3, Table 12) (Fitch-Snyder and Schulze 2001).

Results strongly suggest that pygmy slow lorises housed in an enclosure with another species have a higher breeding success than those housed as a single-species exhibit (Chapter Four, Section 4.4). The author stresses to importance of further research in this subject area in order to determine a conclusive result.

The study brings to light the limited nutritional information available for captive lorises. In order for zoos to provide their animals with the optimal nutritional requirements for the species more research is greatly needed. Nutrition has been found to link to the reproductive rate of natural animal populations (Hume 1995 cited by Schwitzer and Kaumanns 2009). Therefore through defining the correct nutritional requirements for lorises the success of breeding the species in captivity could potentially increase.

Results highlight that 80% of European zoos feed their grey slender and pygmy slow lorises at the same time each day (Table 14). This regularity in feeding has been found to promote pre-feeding anticipation, a key factor that contributes to the development of stereotypic behaviour in captive animals (Hosey *et al* 2009).

Since husbandry guidelines were published it has been discovered that pygmy slow lorises are obligate gummivores (Starr and Nekaris 2013). Original guidelines mention feeding gum to captive lorises; however the amount that should be given was not specified (Fitch-Snyder and Schulze 2001). In this study only two institutions were found to feed gum to their captive pygmy slow loris as part of their regular diet (Table 13). Nekaris *et al* (2010) suggested that captive environments should allow lorises to carry out gouging behaviours in order to prevent periodontal diseases.

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Appendix 1a

Paired t-test results on differences between birth and death rates in the international captive population of aye-aye using SPSS statistical computer software

T-Test

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Birth Rate	96.1818	22	61.01572	13.00859
	Death Rate	93.2727	22	86.87330	18.52145

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Birth Rate & Death Rate	22	.121	.590

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Birth Rate - Death Rate	2.90909	99.91468	21.30188	-41.39060	47.20878	.137	21	.893

Appendix 1b

Paired t-test results on differences between birth and death rates in the European captive population of fat-tailed dwarf lemur using SPSS statistical computer software

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Birth Rate	87.4748	21	72.62295	15.84763
	Death Rate	91.9862	21	49.14367	10.72403

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Birth Rate & Death Rate	21	-.128	.580

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Birth Rate - Death Rate	-4.51143	92.75248	20.24025	-46.73185	37.70899	-.223	20	.826

Appendix 1c

Paired t-test results on differences between birth and death rates in the European captive population of Goodman's mouse lemur using SPSS statistical computer software

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Birth Rate	234.2467	15	194.24692	50.15434
	Death Rate	24.3447	15	38.99665	10.06889

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Birth Rate & Death Rate	15	-.009	.975

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Birth Rate - Death Rate	209.90200	198.46602	51.24371	99.99518	319.80882	4.096	14	.001

Appendix 1d

Paired t-test results on differences between birth and death rates in the European captive population of grey mouse lemur using SPSS statistical computer software

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Birth Rate	176.9405	22	88.48545	18.86516
	Death Rate	151.8864	22	47.90637	10.21367

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Birth Rate & Death Rate	22	.403	.063

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Birth Rate - Death Rate	25.05409	81.91112	17.46351	-11.26326	61.37145	1.435	21	.166

Appendix 1e

Paired t-test results on differences between birth and death rates in the European captive population of grey slender loris using SPSS statistical computer software

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Birth Rate	136.9557	21	59.61564	13.00920
	Death Rate	173.6676	21	68.04738	14.84915

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Birth Rate & Death Rate	21	.194	.400

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Birth Rate - Death Rate	-36.71190	81.31325	17.74401	-73.72525	.30144	-2.069	20	.052

Appendix 1f

Paired t-test results on differences between birth and death rates in the European captive population of pygmy slow loris using SPSS statistical computer software

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Birth Rate	122.7595	21	51.49410	11.23693
	Death Rate	138.6424	21	36.95116	8.06340

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Birth Rate & Death Rate	21	.292	.200

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Birth Rate - Death Rate	-15.88286	53.91647	11.76554	-40.42534	8.65963	-1.350	20	.192

Appendix 2

Kruskal-Wallis test results on differences between average infant mortality rate using SPSS statistical computer software.

NPar Tests

Kruskal-Wallis Test

Ranks

	Captive Population	N	Mean Rank
Infant Mortality	1.00	1	4.00
	2.00	1	2.00
	3.00	1	1.00
	4.00	1	3.00
	5.00	1	5.00
	6.00	1	6.00
	Total	6	

Test Statistics[a,b]

	Infant Mortality
Chi-Square	5.000
df	5
Asymp. Sig.	.416

a. Kruskal Wallis Test

b. Grouping Variable: Captive Population

Appendix 3a

Chi-square test results on differences between the age groups of males and females within captive population of aye-aye using SPSS statistical computer software

Crosstabs

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Age Group * Sex	16	100.0%	0	.0%	16	100.0%

Age Group * Sex Crosstabulation

			Sex		
			Male	Female	Total
Age Group	0-4 years old	Count	2	0	2
		Expected Count	1.0	1.0	2.0
	5-9 years old	Count	0	2	2
		Expected Count	1.0	1.0	2.0
	10-14 years old	Count	2	3	5
		Expected Count	2.5	2.5	5.0
	15-19 years old	Count	2	0	2
		Expected Count	1.0	1.0	2.0
	20-24 years old	Count	1	1	2
		Expected Count	1.0	1.0	2.0
	25-29 years old	Count	1	0	1
		Expected Count	.5	.5	1.0
	30-34 years old	Count	0	2	2
		Expected Count	1.0	1.0	2.0
Total		Count	8	8	16
		Expected Count	8.0	8.0	16.0

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	9.200[a]	6	.163
Likelihood Ratio	12.678	6	.048
Linear-by-Linear Association	.439	1	.508
N of Valid Cases	16		

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	9.200[a]	6	.163
Likelihood Ratio	12.678	6	.048
Linear-by-Linear Association	.439	1	.508
N of Valid Cases	16		

a. 14 cells (100.0%) have expected count less than 5. The minimum expected count is .50.

Appendix 3b

Chi-square test results on differences between the age groups of males and females within captive population of fat-tailed dwarf lemur using SPSS statistical computer software

Crosstabs

Case Processing Summary

	Cases					
	Valid		*Missing*		*Total*	
	N	*Percent*	*N*	*Percent*	*N*	*Percent*
*Age Group * Sex*	*20*	*100.0%*	*0*	*.0%*	*20*	*100.0%*

Age Group * Sex Crosstabulation

			Sex		
			Male	Female	Total
Age Group	0-4 years old	Count	2	1	3
		Expected Count	1.3	1.7	3.0
	5-9 years old	Count	2	4	6
		Expected Count	2.7	3.3	6.0
	10-14 years old	Count	3	4	7
		Expected Count	3.2	3.9	7.0
	15-19 years old	Count	1	2	3
		Expected Count	1.3	1.7	3.0
	20-24 years old	Count	1	0	1
		Expected Count	.5	.6	1.0
Total		Count	9	11	20
		Expected Count	9.0	11.0	20.0

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	2.299[a]	4	.681
Likelihood Ratio	2.688	4	.611
Linear-by-Linear Association	.004	1	.951
N of Valid Cases	20		

a. 10 cells (100.0%) have expected count less than 5. The minimum expected count is .45.

Appendix 3c

Chi-square test results on differences between the age groups of males and females within captive population of Goodman's mouse lemur using SPSS statistical computer software

Crosstabs

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Age Group * Sex	85	10.3%	739	89.7%	824	100.0%

Age Group * Sex Crosstabulation

			Sex		
			Male	Female	Total
Age Group	0-4 years old	Count	35	25	60
		Expected Count	32.5	27.5	60.0
	5-9 years old	Count	7	11	18
		Expected Count	9.7	8.3	18.0
	10-14 years old	Count	4	3	7
		Expected Count	3.8	3.2	7.0
Total		Count	46	39	85
		Expected Count	46.0	39.0	85.0

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	2.136[a]	2	.344
Likelihood Ratio	2.137	2	.344
Linear-by-Linear Association	.630	1	.427
N of Valid Cases	85		

a. 2 cells (33.3%) have expected count less than 5. The minimum expected count is 3.21.

Appendix 3d

Chi-square test results on differences between the age groups of males and females within captive population of grey mouse lemur using SPSS statistical computer software

Crosstabs

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Age Group * Sex	202	27.3%	537	72.7%	739	100.0%

Age Group * Sex Crosstabulation

			Sex		
			Male	Female	Total
Age Group	.00	Count	1	0	1
		Expected Count	.5	.5	1.0
	0-4 years old	Count	63	48	111
		Expected Count	56.6	54.4	111.0
	5-9 years old	Count	35	41	76
		Expected Count	38.8	37.2	76.0
	10-14 years old	Count	4	9	13
		Expected Count	6.6	6.4	13.0
	15-19 years old	Count	0	1	1
		Expected Count	.5	.5	1.0
Total		Count	103	99	202
		Expected Count	103.0	99.0	202.0

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	6.347[a]	4	.175
Likelihood Ratio	7.174	4	.127
Linear-by-Linear Association	5.736	1	.017
N of Valid Cases	202		

a. 4 cells (40.0%) have expected count less than 5. The minimum expected count is .49.

Appendix 3e

Chi-square test results on differences between the age groups of males and females within captive population of grey slender loris using SPSS statistical computer software

Crosstabs

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Age Group * Sex	20	3.7%	517	96.3%	537	100.0%

Age Group * Sex Crosstabulation

			Sex		
			Male	Female	Total
Age Group	0-4 years old	Count	3	6	9
		Expected Count	4.5	4.5	9.0
	5-9 years old	Count	5	2	7
		Expected Count	3.5	3.5	7.0
	10-14 years old	Count	2	2	4
		Expected Count	2.0	2.0	4.0
Total		Count	10	10	20
		Expected Count	10.0	10.0	20.0

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	2.286[a]	2	.319
Likelihood Ratio	2.348	2	.309
Linear-by-Linear Association	.728	1	.394
N of Valid Cases	20		

a. 6 cells (100.0%) have expected count less than 5. The minimum expected count is 2.00.

Appendix 3f

Chi-square test results on differences between the age groups of males and females within captive population of pygmy slow loris using SPSS Statistical computer software

Crosstabs

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Age Group * Sex	85	16.4%	432	83.6%	517	100.0%

Age Group * Sex Crosstabulation

			Sex		
			Male	Female	Total
Age Group	0-4 years old	Count	19	14	33
		Expected Count	18.6	14.4	33.0
	5-9 years old	Count	14	13	27
		Expected Count	15.2	11.8	27.0
	10-14 years old	Count	14	9	23
		Expected Count	13.0	10.0	23.0
	15-19 years old	Count	1	1	2
		Expected Count	1.1	.9	2.0
Total		Count	48	37	85
		Expected Count	48.0	37.0	85.0

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	.466[a]	3	.926
Likelihood Ratio	.466	3	.926
Linear-by-Linear Association	.010	1	.922
N of Valid Cases	85		

a. 2 cells (25.0%) have expected count less than 5. The minimum expected count is .87.

Appendix 4

Completed Faculty Ethics form HSS.E2
Application for ethics approval for a research project involving human participants

Faculty of Humanities and Social Sciences

Application for ethics approval for a research project involving human participants

Undergraduates and Foundation Degree Students:
Before completing this form, the ethics review checklist (school form HSS.E1) should have been completed to establish whether this additional application for ethics approval is required. If ethics approval is required, you should complete this form, sign it and submit it to the Faculty Research Ethics Officer, Maggie Wilson at mvwilson@brookes.ac.uk. A decision form, E3 will then be returned to you by e-mail.

Master's Students:
You should complete this form before you start your project and submit it to your supervisor.
If he or she is unable to sign it at this stage, the form will be referred to the Faculty Research Ethics Officer, as above, who may seek further information and clarification from you. A decision form, E3, will then be returned to you by e-mail.

All students should refer to the University Code of Practice on Ethical Standards for Research involving Human Participants, available at www.brookes.ac.uk/res/ethics and Faculty guidelines, which are included in the relevant on-line module or course handbook. You should bind a copy of the approved form in your final project or dissertation submission.

1.	Name of Principal Investigator (Student):	Anna Elvidge
	E-mail address:	anna.holt-2011@brookes.ac.uk
2.	Name of Supervisor and e-mail address:	Professor Anna Nekaris
	E-mail address:	anekaris@brookes.ac.uk
3.	Working Project Title:	Do husbandry techniques affect the breeding success of captive lorises?
4.	Project Type (please specify course and give module number):	Master's project
		Master's dissertation: Masters by Research Thesis
		Undergraduate project:
		Undergraduate

dissertation:

Foundation
degree project:

5. Background to and rationale of proposed research:

The proposed study will look into the European captive population of pygmy slow loris (*Nycticebus pygmaeus*) and grey slender loris (*Loris lydekkerianus nordicus*). The study will investigate the captive requirements of these species to determine if husbandry methods affect breeding success.

Populations of pygmy slow loris and grey slender loris are considered threatened in the wild and have declining population trends (IUCN 2012). A conservation role of zoos is to provide an extinction safety net for threatened species. In order for zoos to maintain captive populations they need to be self-sustaining (Hosey *et al* 2009; Lees and Wilcken 2009).

Captive population studies on pygmy slow loris and grey slender loris are limited (Riewald et al unpublished). A recent rapid study on the sustainability of EAZA's mammal populations revealed that the grey slender loris population failed three of five sustainability categories (Riewald et al unpublished). The captive population was found to contain less than 50 individuals, have low growth rates and contain less than 30 known founders within their population (Riewald et al unpublished). The European captive population of pygmy slow loris has seen a decline in the population between the years 2001-2010 (Trzeswoska 2011).

A key part of maintaining captive populations is good management (Baker 2007). Kaumanns *et al* 2008 suggests that low growth rates in primates are linked to their captive environment. The husbandry manual for lorises was written twelve years ago (Fitch-Synder and Schulze 2000). At the time of writing this manual no long-term study on wild lorises had been completed in detail and therefore little was known about their species specific requirements.

This study will look into the reasons why the European captive populations of pygmy slow loris and grey slender loris are exhibiting low growth rates. The aim of the study is to determining if husbandry routines affect breeding success. The study hopes to update husbandry guidelines by making husbandry recommendations based on the results of this study and published research. The results and recommendations from this study could help to increase breeding success and the sustainability

of these captive populations in the future.

References

Baker A (2007) Animal ambassadors: an analysis of the effectiveness and conservation impact of ex-situ breeding efforts. In Zimmermann A, Hatchwell M, Dickie L and West C. (eds.). *Zoos in the 21st century, catalysts for conservation?.* Cambridge: Cambridge University Press. 139-154.

Fitch-Snyder H and Schulze H (eds.) (2000) *Management of lorises in captivity: a husbandry manual for Asian loridae (Nycticebus & Loris ssp.)*. San Diego: Center of Reproduction of Endangered Species.

Hosey G, Melfi V and Pankhurst S (2009) *Zoo animals: behaviour, management and welfare.* Oxford: Oxford University Press.

IUCN (2012) The IUCN red list of endangered species. Available at: http://www.iucnredlist.org/ (Accessed: 23 April 2012)

Kaumanns W, Singh M, Krebs E and Schwitzer C (2008) Primate populations in zoos: a case of fragmentation. *Primate Report*. 76, 1-14.

Lees C M and Wilcken J (2009) Sustaining the ark: the challenges faced by zoos in maintaining viable populations. *International Zoo Yearbook* 43, 6-18.

Riewald S, Veldkamp A, Wijmans J, Leus K, Bingaman Lackey, L. and De Man D (unpublished) Sustainability of EAZA mammal populations.

Trzeswoska E (2011) EAZA Nocturnal Prosimian TAG Workshop. *Pygmy slow loris; what we succeeded and what failed*. April 2. Frankfurt: Frankfurt Zoo.

6.	‘Gatekeeper’ permission If you are conducting your research within an organisation external to Brookes, such as a school or company, has permission been obtained? Attach a copy of the letter or e-mail giving permission	N/A
7	Methods of data collection: Attach a copy of your draft questionnaire, interview schedule or	Questionnaire (attached). This document will be emailed to the participants.

	observation guidelines	
8	Participants involved in the research: Include the target number, age range, source and method of recruitment and location of the research	27 European zoological institutions will be contacted for this study. These institutions all have a captive population of lorises. The zoo keeper caring for this population will be the participant.
9	Are participants in a dependent relationship)as an unequal power relationship) with the researcher? If yes, what steps will you take to ensure that participation is entirely voluntary and is not influenced by this relationship?	No
10.	Potential benefits of the proposed research:	This study aims to determine if there is a relationship between husbandry routines and breeding success in captive lorises. Identifying if certain husbandry routines affect breeding could help zoo managers to manage the captive population effectively potentially increasing future breeding success. Results and recommendations from this study will be distributed to the European zoos holding the study species and the EAZA Prosimian Taxonomic Advisory Group. This group is responsible for making captive breeding recommendations to the European zoo community.
11	Potential adverse effects of the proposed research and steps to be taken to deal with them: These are defined as risks greater than those encountered during normal day to day interactions and could include possible psychological stress or anxiety	There are no potential adverse effects of the proposed research. The participant is not the subject of the research.
12.	Plan for obtaining informed consent: Please attach copy of your participant information sheet and consent form (Note consent forms are not needed for questionnaires)	The questionnaire will be emailed to the participant. No consent form is required for this method as consent is implied by returning the questionnaire.
13.	Steps to be taken to ensure confidentiality of data: Outline steps to be taken to ensure confidentiality, privacy and anonymity of data during collection and	Participants will be informed that all data supplied will be confidential and will be presented in such a way that the name of the participant cannot be identified.

publication of data

14	Debriefing and/or feedback to participants What debriefing and support will participants receive after the research? How will findings of the research be made available to them?	The results and recommendations from this study will be distributed to all the participating European zoos.
15	Data storage and security How will you ensure safe data storage during fieldwork and after publication?	All electronic files will be password protected to ensure security of this data. As above

All materials submitted will be treated confidentially.

I have read and understood the University's Code of Practice on Ethical Standards for Research involving Human Participants

Signed:  Principal Investigator /Student

Signed:  Supervisor

Date:
05/02/13

Appendix 5

Completed E3/FH & LS form
Decision on application of ethics approval

E3/FH&LS

Oxford Brookes University

Faculty of Health and Life Sciences

Decision on application for ethics approval

The Departmental Research Ethics Officer (DREO) / Faculty Research Ethics Committee (FREC) has considered the application for ethics approval for the following project:

Project Title:

Name of Applicant/s: Anna Elvidge

Name of Supervisor/s: Anna Nekaris

Please tick one box

1. The Departmental Research Ethics Officer / Faculty Research Ethics Committee gives ethical approval for the research project. [x]

Please note that the research protocol as laid down in the application and hereby approved must not be changed without the approval of the DREO / FREC

2. The Departmental Research Ethics Officer / Faculty Research Ethics Committee gives ethical approval for the research project, subject to the following:: [ ]

3. The Departmental Research Officer / Faculty Research Ethics Committee cannot give ethical approval for the research project. The reasons for this and the action required are as follows: [ ]

Signed: …… Approval Date: 15 Sept 2011…..……

Designation: Departmental Research Ethics Officer

(Signed on behalf of the Faculty Research Ethics Committee)

Date when application reviewed (*office use only*):…10 Sept 2011……

H&LS/FRec/E3 August 2011

Appendix 6

Husbandry and Breeding Questionnaire on Captive Lorises within European Zoos

Husbandry and Breeding Questionnaire on Captive Lorises within European Zoos

This questionnaire forms part of an MSc by Research project at Oxford Brookes University. This study focuses on the European captive populations of pygmy slow loris (*Nycticebus pygmaeus*) and the grey slender loris (*Loris lydekkerianus nordicus*). The aim of the study is to discover if there is a relationship between husbandry techniques and breeding success. The data collected from this survey will be measured against captive population data to find out if the captive environment affects the breeding success of these species. Results from this research hope to allow husbandry recommendations to be made that could potentially increase the health and breeding success of these captive populations in the future. These recommendations will involve easily implemented changes to enclosures and husbandry routines. The results and recommendations from this study will be distributed to the European zoo community and the EAZA Prosimian TAG.

The information you provide below will only be used for the study mentioned above. All your responses within this questionnaire will be treated with confidence and at all times data will be presented in such a way that your institutes' identity cannot be connected with specific published data. Your participation is completely voluntary and you can withdraw at any time.

Thank you for taking the time to review my questionnaire, I hope you find my research of interest and are able to participate in this study. Any information you can provide below will be gratefully received and will be extremely valuable to my research.

Name and address of your zoological institution:

1. Captive Population

a) What species of loris does your institute hold (please fill in a separate questionnaire for each different species held)?

Grey Slender Loris *Pygmy Slow Loris* *(delete as applicable)*

b) How many individuals are housed at your institute?
c) Please list the studbook numbers (if known):

d) Total number of males: Approx. age(s):
e) Total number of females: Approx. age(s):

2. Diet

a) Please give details of the current diet fed to your lorises (if possible please include a copy of your diet sheet with the completed questionnaire):

b) Do you vary their diet according to the season? *Yes No (delete as applicable)*
If yes, please give details of any seasonal changes:

c) Is gum-based enrichment provided? *Yes No (delete as applicable)*
If yes, please specify type & the frequency given:

d) How often are the lorises fed? *Once a day Twice a day Three times a day*
Other (please specify) (delete as applicable)

e) What times of the day are the animals fed?

f) Are the animals fed at the same times each day? *Yes No (delete as applicable)*
If no, please explain your feeding pattern:

g) How is the food presented? *In a bowl Scattered around enclosure*
Other (please specify) (delete as applicable)

3. Husbandry Routine

a) Is the enclosure cleaned daily? *Yes No (delete as applicable)*
If no, please state frequency:

b) Please explain your general cleaning routine:

c) How often does the floor substrate get replaced?
Weekly Monthly Other (please specify) (delete as applicable)

d) How often is the enclosure furniture deep cleaned (e.g. fixed furniture used for climbing)?
Monthly Every 3 months Every 6 months Other (please specify) (delete as applicable)

e) How often is the enclosure furniture changed/re-designed?
Every 3 months Every 6 months Once a year Other (please specify) (delete as applicable)

f) How many different keepers look after the species?
g) How many times in one day does a keeper enter the enclosure?
Once Twice Three times Other (please specify) (delete as applicable)

h) In a 24 hour period, please estimate the total duration of time that a keeper is present in the enclosure?

4. **<u>Enclosure Information</u>**

a) Please fill in the following table with the details of each loris enclosure at your institute.

Enclosure Number	**Approx. width of Enclosure** (Metres)	**Approx. depth of Enclosure** (Metres)	**Approx. height of Enclosure** (Metres)	**Number of males in the enclosure**	**Number of females in the enclosure**	**Is there access to outdoors?** (tick as appropriate)		**Is the enclosure on show to the public?** (tick as appropriate)		**Amount of enclosure that can be accessed for viewing by visitors** (tick as appropriate)				**Is the enclosure mixed with other species?** (tick as appropriate)		**List the species housed in the neighbouring enclosure(s)**
						Yes	No	Yes	No	1/4	1/2	3/4	all	Yes (please give name/s of other species)	No	
1																
2																
3																
4																
5																
6																

b) Are any of the individuals that are housed together related? *Yes No N/A (delete as applicable)*

If yes, please give relevant enclosure number(s) and type of relationship (e.g. parent and offspring):

c) Are any individuals housed as a breeding pair? *Yes No (delete as applicable)*

If yes, please give relevant enclosure number(s):

5. Environmental Conditions

5.1 Lighting

a) Are your loris enclosures situated within a nocturnal animal house?

Yes No Other (please specify) (delete as applicable)

b) How is the enclosure lighting operated?

Manually Digitally controlled by a timer Other (please specify) (delete as applicable)

c) Is the enclosure lighting kept on a reverse light cycle (e.g. lighting simulates night-time during daylight hours)? *Yes No (delete as applicable)*

Please give: Approximate hours of daylight: Approximate hours of darkness:

d) Do the lights fade slowly from dark –light and vice versa to simulate dawn and dusk?

Yes No (delete as applicable)

e) Do the light levels vary during the year to simulate changes in season?

Yes No (delete as applicable)

If yes, please explain the variance:

f) Does the visitor viewing area outside the enclosure also simulate the same light conditions?

No Yes (delete as applicable)

If no, please explain the lighting schedule used:

g) What type of artificial lighting is used to simulate daylight in the enclosure (e.g. strip lights)?

h) What type of artificial lighting is used to simulate night-time hours (e.g. dimmed infra-red spots)?

i) How many hours in a 24hr period is the enclosure in complete darkness?

5.2 Temperature

a) What temperature (°C) do you keep the enclosure at?

b) Do the temperature levels get varied during different times of day (e.g. lower temperature at night)?

Yes No (delete as applicable)

If yes, please explain how the temperature is varied:

c) How is the enclosure heated (e.g. with a heater/heat lamps)?

d) Do you vary the temperature throughout the year to simulate changes in season (e.g. cooler during winter months)?

Yes No (delete as applicable)

If yes, please give detail of any changes:

5.3 Humidity

a) What level of humidity (%) do you keep the enclosure at?

b) Do you vary the humidity levels throughout the day? *Yes No (delete as applicable)*

If yes, please explain variance used:

c) Do you vary the percentage of humidity throughout the year to simulate seasons?

Yes No (delete as applicable)

If yes, please explain the variance:

d) How is the humidity within the enclosure maintained (e.g. humidifier/ substrate misted daily)?

6. Enclosure Furniture

a) Please complete the following table on different types of enclosure furniture/climbing substrate. Please indicate using an 'X' what furniture is available to the loris at different levels of the enclosure.

Enclosure Furniture	**Enclosure levels**		
	Lower (0-1m above cage floor)	**Middle (1-2m above cage floor)**	**Upper (2-3m above cage floor)**
Horizontal timber branches			
Vertical timber branches			
Tree Trunks			
Shelf			
Nest box			
Plant foliage			
Wire mesh walls			
Other (please specify)			

b) Do the rounded timber branches that are used as climbing furniture within the enclosure vary in diameter? *Yes No (delete as applicable)*

c) What is the approximate diameter of the horizontal branches within the enclosure?

0-2cm, 3-5cm, 6-8cm, 9-11cm (delete any that do not apply)

d) What is the approximate diameter of the vertical branches within the enclosure?
0-2cm, 3-5cm, 6-8cm, 9-11cm (delete any that do not apply)

e) Does the climbing structure provide the animals with a continuous pathway around the enclosure (e.g. gaps between the branches are close enough together for the animal to reach without having to jump)? *Yes No (delete as applicable)*
If no, please give details of the climbing structure used:

f) What type of substrate is used on the ground?
Shredded bark/Wood shavings/Straw/Leaf litter/ Boxes /Other (please specify)
(Please delete all substrates that do not apply)

g) Does the furniture allow the loris to gain easy access to the ground?
Yes No (delete as applicable)
h) Are any areas within the enclosure empty of furniture?
Yes No (delete as applicable)
If yes, please describe where empty space occurs and give approx. % of empty space:

i) How many nest boxes are available in each enclosure?

7. Breeding

a) Is your institution actively breeding this species? *Yes No (delete as applicable)*
If no, please go to question 7 (l).

b) Total number of breeding males (please give studbook numbers if known):
c) Total number of breeding females (please give studbook numbers if known):
d) Do these individuals only mix at breeding time? *Yes No (delete as applicable)*
If no, please explain breeding routine:

e) Are any other species present in the enclosure during breeding?
Yes No (delete as applicable)
If yes, please provide species name(s):

f) How many times a year does your institute attempt to breed these animals?

g) What was the date of the last breeding attempt?
Was it successful? *Yes No (delete as applicable)*
h) What was the date of the last successful breeding (if different from above)?

i) How many births have there been since the beginning of January 2011?

j) Please give approximate dates of births of all individuals born since the beginning of Jan 2011:

k) How many of these individuals are currently still living (please give details of any deaths and the causes)?

l) Did your institute used to actively breed this species?

Yes *No* *N/A* *(delete as applicable)*

If yes, please provide dates and outcome of the last breeding attempt:

8. Additional Comments

If you have any additional information on your loris population that you think may be helpful to my research please include it in the space below. Please fill free to attach additional sheets if needed.

Personal Information

All personal information given below will be as treated as strictly confidential.

Name: Position held within institute:

Contact email:

Signature: Date completed:

If you're happy for your institutions name to be included in a list of participants that contributed to this research please tick the following box ☐

I would like to sincerely thank you for taking the time to fill in this questionnaire, your responses will play an extremely valuable part of my research and I am extremely grateful for your contribution.

Please return the completed questionnaire, along with your loris diet sheet and any other additional information you think may be helpful to: anna.holt-2011@brookes.ac.uk

Alternatively, please post the questionnaire to the below address:

Ms Anna Elvidge
14 Nympsfield Road
Nailsworth
Gloucestershire
GL6 0EE
UK

Please can you return the completed questionnaire by **Monday 22nd October 2012**, thank you.

Appendix 7

Letter of Support from the EAZA Prosimian TAG Chair Achim Johann

Prosimian TAG
EAZA

To whom it may concern

Letter of support

Anna Holt is starting a comprehensive study on breeding-programmes for nocturnal prosimians focussing on management and husbandry of selected taxa.

I discussed with Anna lengthy the layout of such a study and pointed on the difficulties to collect data from current studbooks and files from the individual zoos which must be considered when doing statistical analyses and drawing conclusions. Also I recommended to focus on the EEPs for pygmy slow loris and slender loris as there are more accurate and anyway comprehensive data available whereas the ESBs for mouse lemurs and galagos still are in the process to verify taxonomic identies of the animals included. Finally, sample size for fat-tailed dwarf lemurs might be too small to be considered.

Beside these objections regarding the practicability of the study I am convinced that Anna`s study will be one of importance for the Prosimian TAG in the way that we can expect results which will lead to improved husbandry for some of the species covered.

The scientific guidance of Anna`s study is guaranteed by Anna Nekaris of Oxford Bookes University and and Christoph Schwitzer, Bristol Zoo.
Also Anna got first hand knowledge on the TAG`s work and the respecive EEPs and ESBs when she participated the Nocturnal Prosimians Workshop in April 2011 in Frankfurt.

I kindly ask you to support Anna`s study as appropriate.

Achim Johann
Chair EAZA Prosimian TAG

Appendix 8a

Regression test results on instituion breeding success and number of feeds a day using SPSS statistical computer software

Regression

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	Number of feeds	.	Enter

a. All requested variables entered.

b. Dependent Variable: Breeding Success

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.222[a]	.049	-.024	.82667

a. Predictors: (Constant), Number of feeds

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.460	1	.460	.674	.427[a]
	Residual	8.884	13	.683		
	Total	9.344	14			

a. Predictors: (Constant), Number of feeds

b. Dependent Variable: Breeding Success

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.703	.503		1.396	.186
	Number of feeds	.244	.297	.222	.821	.427

a. Dependent Variable: Breeding Success

Appendix 8b

Regression test results on instituion breeding success and volume of enclosure using SPSS statistical computer software

Regression

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	Volume of enclosure	.	Enter

a. All requested variables entered.

b. Dependent Variable: Breeding Success

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.334[a]	.111	.037	.79860

a. Predictors: (Constant), Volume of enclosure

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.959	1	.959	1.504	.244[a]
	Residual	7.653	12	.638		
	Total	8.612	13			

a. Predictors: (Constant), Volume of enclosure

b. Dependent Variable: Breeding Success

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.337	.269		4.968	.000
	Volume of enclosure	-.006	.005	-.334	-1.226	.244

a. Dependent Variable: Breeding Success

Appendix 8c

Regression test results on instituion breeding success and number of nest boxes within enclosure using SPSS statistical computer software

Regression

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	Number of nest boxes	.	Enter

a. All requested variables entered.

b. Dependent Variable: Breeding Success

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.024[a]	.001	-.076	.84757

a. Predictors: (Constant), Number of nest boxes

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.006	1	.006	.008	.931[a]
	Residual	9.339	13	.718		
	Total	9.344	14			

a. Predictors: (Constant), Number of nest boxes

b. Dependent Variable: Breeding Success

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.045	.419		2.496	.027
	Number of nest boxes	.018	.206	.024	.088	.931

a. Dependent Variable: Breeding Success

Appendix 8d

Regression test results on instituion breeding success and average hours of daylight over a 24 hour period using SPSS statistical computer software

Regression

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	Hours of daylight	.	Enter

a. All requested variables entered.

b. Dependent Variable: Breeding Success

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.007[a]	.000	-.083	.81608

a. Predictors: (Constant), Hours of daylight

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.000	1	.000	.001	.981[a]
	Residual	7.992	12	.666		
	Total	7.992	13			

a. Predictors: (Constant), Hours of daylight

b. Dependent Variable: Breeding Success

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.918	3.276		.280	.784
	Hours of daylight	.006	.268	.007	.024	.981

a. Dependent Variable: Breeding Success

Appendix 8e

Regression test results on instituion breeding success and average hours of darkness over a 24 hour period using SPSS statistical computer software

Regression

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	Hours of darkness	.	Enter

a. All requested variables entered.

b. Dependent Variable: Breeding Success

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.007[a]	.000	-.083	.81608

a. Predictors: (Constant), Hours of darkness

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.000	1	.000	.001	.981[a]
	Residual	7.992	12	.666		
	Total	7.992	13			

a. Predictors: (Constant), Hours of darkness

b. Dependent Variable: Breeding Success

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.073	3.169		.339	.741
	Hours of darkness	-.006	.268	-.007	-.024	.981

a. Dependent Variable: Breeding Success

Appendix 8f

Regression test results on instituion breeding success and average enclosure temperature using SPSS statistical computer software

Regression

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	Enclosure temperature	.	Enter

a. All requested variables entered.

b. Dependent Variable: Breeding Success

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.086[a]	.007	-.092	.84400

a. Predictors: (Constant), Enclosure temperature

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.053	1	.053	.075	.790[a]
	Residual	7.123	10	.712		
	Total	7.177	11			

a. Predictors: (Constant), Enclosure temperature

b. Dependent Variable: Breeding Success

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.693	2.482		.682	.511
	Enclosure temperature	-.029	.105	-.086	-.274	.790

a. Dependent Variable: Breeding Success

Appendix 8g

Regression test results on instituion breeding success and relative humidity of enclosure using SPSS statistical computer software

Regression

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	Relative Humidity	.	Enter

a. All requested variables entered.

b. Dependent Variable: Breeding Success

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.236[a]	.056	-.062	.68503

a. Predictors: (Constant), Relative Humidity

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.222	1	.222	.473	.511[a]
	Residual	3.754	8	.469		
	Total	3.976	9			

a. Predictors: (Constant), Relative Humidity

b. Dependent Variable: Breeding Success

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.208	1.800		-.116	.911
	Relative Humidity	.018	.027	.236	.688	.511

a. Dependent Variable: Breeding Success

Appendix 8h

Regression test results on instituion breeding success and duration of time a keeper is inside an enclosure using SPSS statistical computer software

Regression

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	Amount of time keeper is in enclosure	.	Enter

a. All requested variables entered.

b. Dependent Variable: Breeding Success

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.287[a]	.082	.012	.81211

a. Predictors: (Constant), Amount of time keeper is in enclosure

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.771	1	.771	1.168	.299[a]
	Residual	8.574	13	.660		
	Total	9.344	14			

a. Predictors: (Constant), Amount of time keeper is in enclosure

b. Dependent Variable: Breeding Success

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.367	.341		4.009	.001
	Amount of time keeper is in enclosure	-.010	.009	-.287	-1.081	.299

a. Dependent Variable: Breeding Success

Appendix 8i

Regression test results on instituion breeding success and number of different keepers looking after the animals using SPSS statistical computer software

Regression

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	Number of different keepers	.	Enter

a. All requested variables entered.

b. Dependent Variable: Breeding Success

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.081[a]	.007	-.070	.84502

a. Predictors: (Constant), Number of different keepers

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.062	1	.062	.086	.774[a]
	Residual	9.283	13	.714		
	Total	9.344	14			

a. Predictors: (Constant), Number of different keepers

b. Dependent Variable: Breeding Success

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.944	.502		1.880	.083
	Number of different keepers	.030	.103	.081	.294	.774

a. Dependent Variable: Breeding Success

Appendix 9a

Kendall rank-order correlation test results on instituion breeding success and frequency fixed furniture is cleaned using SPSS statistical computer software

Nonparametric Correlations

Correlations

			Breeding Success	Fixed furniture cleaned
Kendall's tau_b	Breeding Success	Correlation Coefficient	1.000	.491*
		Sig. (2-tailed)	.	.030
		N	13	13
	Fixed furniture cleaned	Correlation Coefficient	.491*	1.000
		Sig. (2-tailed)	.030	.
		N	13	13

*. Correlation is significant at the 0.05 level (2-tailed).

Appendix 9b

Kendall rank-order correlation test results on instituion breeding success and mixed-species exhibits using SPSS statistical computer software

Nonparametric Correlations

Correlations

			Institution breeding success	Mixed species exhibit
Kendall's tau_b	Institution breeding success	Correlation Coefficient	1.000	.571*
		Sig. (2-tailed)	.	.037
		N	11	11
	Mixed species exhibit	Correlation Coefficient	.571*	1.000
		Sig. (2-tailed)	.037	.
		N	11	11

*. Correlation is significant at the 0.05 level (2-tailed).

Appendix 9c

Kendall rank-order correlation test results on instituion breeding success and frequency floor substrate was replaced using SPSS statistical computer software

Nonparametric Correlations

Correlations

			Breeding Success	Frequency floor substrate is cleaned
Kendall's tau_b	Breeding Success	Correlation Coefficient	1.000	.167
		Sig. (2-tailed)	.	.451
		N	13	13
	Frequency floor substrate is cleaned	Correlation Coefficient	.167	1.000
		Sig. (2-tailed)	.451	.
		N	13	13

Appendix 9d

Kendall rank-order correlation test results on instituion breeding success and presentation method of food using SPSS statistical computer software

Nonparametric Correlations

Correlations

			Breeding Success	Presentation of food
Kendall's tau_b	Breeding Success	Correlation Coefficient	1.000	-.012
		Sig. (2-tailed)	.	.957
		N	15	15
	Presentation of food	Correlation Coefficient	-.012	1.000
		Sig. (2-tailed)	.957	.
		N	15	15

Appendix 9e

Kendall rank-order correlation test results on instituion breeding success and provision of gum-enrichment using SPSS statistical computer software

Nonparametric Correlations

Correlations

			Breeding Success	Gum enrichment used
Kendall's tau_b	Breeding Success	Correlation Coefficient	1.000	-.171
		Sig. (2-tailed)	.	.460
		N	15	15
	Gum enrichment used	Correlation Coefficient	-.171	1.000
		Sig. (2-tailed)	.460	.
		N	15	15

Appendix 9f

Kendall rank-order correlation test results on instituion breeding success and reverse light cycle using SPSS statistical computer software

Nonparametric Correlations

Correlations

			Breeding Success	Reverse light cycle
Kendall's tau_b	Breeding Success	Correlation Coefficient	1.000	.057
		Sig. (2-tailed)	.	.805
		N	15	15
	Reverse light cycle	Correlation Coefficient	.057	1.000
		Sig. (2-tailed)	.805	.
		N	15	15

Appendix 9g

Kendall rank-order correlation test results on instituion breeding success and light levels varied through the year using SPSS statistical computer software

Nonparametric Correlations

Correlations

			Breeding Success	Vary light levels
Kendall's tau_b	Breeding Success	Correlation Coefficient	1.000	.315
		Sig. (2-tailed)	.	.173
		N	15	15
	Vary light levels	Correlation Coefficient	.315	1.000
		Sig. (2-tailed)	.173	.
		N	15	15

Appendix 9h

Kendall rank-order correlation test results on instituion breeding success and temperature levels varied through the year using SPSS statistical computer software

Nonparametric Correlations

Correlations

			Breeding Success	Vary enclosure temperature
Kendall's tau_b	Breeding Success	Correlation Coefficient	1.000	-.054
		Sig. (2-tailed)	.	.816
		N	15	15
	Vary enclosure temperature	Correlation Coefficient	-.054	1.000
		Sig. (2-tailed)	.816	.
		N	15	15