Old World Monkeys in Mixed Species Exhibits

(GaiaPark Kerkrade, 2010)

Elwin Kraaij & Patricia ter Maat

University of Applied Sciences
VAN HALL LARENSTEIN
PART OF WAGENINGEN UR

Apenheul

Old World Monkeys in Mixed Species Exhibits

Factors influencing the success of old world monkeys in mixed species exhibits

Authors: Elwin Kraaij & Patricia ter Maat
Supervisors Van Hall Larenstein: T. Griede & M. Dobbelaar
Client: T. ter Meulen, Apenheul
Thesis number: 594000
Van Hall Larenstein
Leeuwarden, August 2011

Preface

This report was written in the scope of our final thesis as part of the study Animal Management. The research has its origin in a request from Tjerk ter Meulen (vice chair of the Old World Monkey TAG and studbook keeper of Allen's swamp monkeys and black mangabeys at Apenheul Primate Park, the Netherlands). As studbook keeper of the black mangabey and based on his experiences from his previous position at Gaiapark Kerkrade, the Netherlands, where black mangabeys are successfully combined with gorillas, he requested our help in researching what factors contribute to the success of old world monkeys in mixed species exhibits.

We could not have done this research without the knowledge and experience of the contributors and we would therefore like to thank them for their help. First of all Tjerk ter Meulen, the initiator of the research for providing information on the subject and giving feedback on our work. Secondly Tine Griede and Marcella Dobbelaar, being our two supervisors from the study Animal Management, for giving feedback and guidance throughout the project.

Finally we would like to thank all zoos that filled in our questionnaire and provided us with the information required to perform this research. We would like to thank the following people: S. Hofman (Antwerpen), T. ter Meulen (Apeldoorn), M. T. Abelló (Barcelona), L. Versteege (Beekse Bergen), A. Dazord (Bourbansain), W. Ludwig (Dresden), G.F. Hoyo (Fuengirola), J. Heuer (Halle), F. Grause (Hannover), S. Reichler-danielowski (Heidelberg), H. Verberkmoes (Kerkrade), J. Pullen (Marwell), S. Klomburg (Osnabrück), A. Johann (Rheine), H. Schmidt (Rotterdam), M. Holtkötter (Stuttgart), G. F. Hoyo (Valencia) and L. Bosworth (Woburn).

Elwin Kraaij & Patricia ter Maat
Leeuwarden, August 2011

Summary

In zoos there is a lack of space for old world monkeys as enclosures become bigger and more naturalistic, because of the advances in enclosure design. A potential solution is housing old world monkey species in mixed species exhibits. The main question to research this potential is: Which of the TAG recommended captive old world monkey species are successfully kept in mixed species exhibits and which factors influence this success? Information to answer this question was gathered by means of a literature research and a questionnaire sent to European zoos keeping old world monkeys in mixed species exhibits. Every situation was reported as successful or not and then factors possibly influencing this success were determined. These were determined by looking at how often they were applied and then at the success and failure percentage with application and non-application. Possible factors were niche occupation, habitat, social structure, species ratio, age class, breeding, size of the enclosure, escape routes, visual barriers, separation period and method of introduction. Finally intervention was researched on how and when it should be applied. In total 71 mixed situations were gathered. These consist of 131 combinations (every animal mixed with a TROWM counted separately, even though in the same exhibit). There are 17 combinations of TROWMs with TROWMs, 51 combinations of TROWMs with non-recommended (OW)Ms and 63 combinations of TROWMs with other animal species. Of the 71 mixed situations found, 60 are successful. The factors size of the enclosure, escape routes, species temperament and individual personality show to have an effect on the success of the mixed situation. Of these escape routes was determined by its high percentage of success when applied and a high failure percentage when not applied. The factors sufficient space, individual personality and species temperament are most often mentioned by the zoos as being important to the outcome of a mixed situation. Niche occupation, habitat, age class and breeding have no effect on the success of a mixed exhibit and social structure, visual barriers and species ratio could not be determined to have an effect on the outcome of a mixed situation. Separation periods and introduction methods are applied in nearly all cases but both in successful and unsuccessful ones. These factors are probably used as a way of preventing conflicts, but could not be proven to actually do this. Application of intervention was only reported by two institutions. Intervention was applied when aggression or stress occurred. For resolving aggression a fire hose was used and for resolving stress the species were temporarily separated. 19 of the 24 TAG recommended old world monkey species have a higher success than failure percentage in mixed species exhibits. 4 others were not mixed at all and of only one the failure percentage was higher than its success percentage. Together with the overall high success percentage of the mixed situations, mixed species exhibits seem a valuable solution to the space issues of this taxon.

Contents

1. Introduction

Historically, exhibits for old world monkeys (*Cercopithecoidae*), like most primate enclosures, are relatively small and intended to house single-species groups. The increase in knowledge of the social and psychological needs of captive primates, along with concern for their physical well-being has created a trend towards larger and more naturalistic enclosures. (Baratay and Hardouin-Fugier, 2002) The development of larger exhibits, however, often results in fewer total exhibits and a reduction in the spaces available for the large number of old world monkey species. (McCann and Carter, 2008) Old world monkeys are of medium to large size (Whitehead and Jolly, 2000) and comprise of 122 species (284 counting subspecies) (IUCN, 2011) including baboons (*Papio Spp.*), colobus monkeys (*Colobus Spp.*), guenons (*Cercopithecus Spp.*), langurs (*Trachipithecus Spp.*), macaques (*Macaca Spp*.), mandrills (*Mandrillus Spp.*), mangabeys (*Cercocebus Spp.*) and meerkats (*Chlorocebus Spp.*) (Wilson and Reeder, 2005). Wild old world monkeys live in Africa and Asia (Whitehead and Jolly, 2000), but their captive conspecifics can be found in zoos all over the world (ISIS, 2011).
The fact that less old world monkey species can be displayed due to the loss of space has a negative effect on educational value (Hosey et al., 2009) and conservation (Dollinger, 2006). It is especially important to ensure both African and Asian old world monkey species are displayed in and distributed over multiple institutions, as this provides an educationally valuable view of this taxon (Hosey et al., 2009) and is important for the conservation of the species (Dollinger, 2006). However only 35% of all old world monkey subspecies is kept in institutions in Europe. (Table 1) Asian species are greatly underrepresented.

Table 1: Comparison of wild and captive number of African and Asian old world monkey species

Region	Total no. subspecies in the wild	No. subspecies in captivity in Europe	% of total
	284	98	35
African	144	67	47
Asian	140	31	22

(IUCN, 2011; ISIS, 2011)

Furthermore for effective conservation it is important to maintain ex-situ populations demographically stable and genetically healthy, through ESBs (European Studbooks) and EEPs (European Endangered species Programmes) (EAZA, 2011). However, due to the above mentioned lack of available spaces for the numerous old world monkey species, combined with the increase of conservation needs of other taxa, it will become increasingly more difficult for zoos to play a significant role in the conservation of old world monkeys.

EAZA's Old World Monkey Taxon Advisory Group (TAG) has recommended 24 old world monkey species that they want to maintain in institutions in Europe. These are the following species:

Table 2: EAZA Old World Monkey TAG recommended species

Common Name	Taxonomic name	ESB / EEP
Allen's swamp monkey	*Allenopithecus nigroviridus*	ESB
Diana monkey	*Cercopithecus diana diana*	EEP
Hamlyn's monkey	*Cercopithecus hamlyni*	EEP
L'Hoest's monkey	*Cercopithecus lhoesti*	EEP
De Brazza's monkey	*Cercopithecus neglectus*	ESB
Roloway monkey	*Cercopithecus diana roloway*	EEP
White-naped mangabey	*Cercocebus atys lunulatus*	EEP
Cherry crowned mangabey	*Cercocebus torquatus*	ESB
Golden bellied mangabey	*Cercocebus chrysogaster*	ESB
Mantled guereza	*Colobus guereza*	ESB
King colobus monkey	*Colobus polykomos*	EEP
Black mangabey	*Lophocebus aterrimus*	ESB
Sulawesi crested macaque	*Macaca nigra nigra*	EEP
Lion-tailed macaque	*Macaca silenus*	EEP
Barbary macaque	*Macaca sylvanus*	ESB
Drill	*Mandrillus leucophaeus*	EEP
Mandrill	*Mandrillus sphinx*	EEP
Northern talapoin Monkey	*Miopithecus ogouensis*	ESB
Guinea baboon	*Papio papio*	ESB
Hanuman langur	*Semnopithecus entellus*	ESB
Gelada	*Theropithecus gelada*	EEP
Javan brown langur	*Trachypithecus auratus auratus*	ESB
Francois' langur	*Trachypithecus francoisi*	ESB
Dusky langur	*Trachypithecus obscurus*	ESB

(EAZA Old World Monkey TAG, minutes TAG meeting, 24 March 2011)

As it is probable that the lack of space in zoos eventually will result in problems concerning the proper (conservation) management of these TAG recommended old world monkeys (TROWMs) in captivity, a further decline of old world monkeys in zoos and loss of educational value regarding this taxon a solution is needed. Different options for solving this problem are possible: keeping fewer species of old world monkeys, allowing hybridization, obtaining founders from the wild/institutions outside Europe and keeping old world monkey species in mixed species exhibits. As the other options still mean a decline in educational and conservation value, mixed species exhibits seem the most suitable solution for the space problem. Besides, mixed species exhibits have important benefits. These are the enriching value to the mixed species, the fact that less space is required to house them and the educational value of the combination with other species (Hosey et al., 2009). However, for zoos to consider this solution, an overview of information and experiences on mixed species exhibits with old world monkeys is needed, including factors influencing success and failure.

1.1 Goal

Provide information on the current status of the TAG recommended old world monkeys in zoos and insights in mixed species exhibits as a potential solution to the space issues for this taxon.

1.2 Research question

Which of the TAG recommended captive old world monkey species are successfully kept in mixed species exhibits and which factors influence this success?

1.2.1 Sub-questions

- What is the status of the TAG recommended old world monkey species in European institutions?
- Which of the TAG recommended old world monkey species are kept in mixed species exhibits?
- What combinations of TAG recommended old world monkey species with other (old world monkey) species are kept?
- What are the most important factors for success of mixed species exhibits with the TAG recommended old world monkeys?
- When and how should intervention take place?

2. Methods

2.1 Research design

The main emphasis of the research is on a questionnaire in which European zoos keeping the TAG recommended species in mixed species exhibits were asked to share their experiences. The questionnaire (appendix 1) was sent to these institutions and after three weeks a reminder was sent. Returned questionnaires were processed as well as information from the literature study. By comparing the processed information, overviews of combinations were created and crucial factors influencing the outcome of these combinations were determined.

2.2 Research population

The research subjects are the situations in which recommended old world monkey species are housed in mixed species exhibits (either mixing old world monkey species or combining them with a different animal species). The Old World Monkey TAG provided a list of zoos which keep the recommended species in Europe. These zoos were sent the questionnaire, because they are most interesting to the European Old World Monkey TAG. In the questionnaire it is clearly stated that all mixed situations with the recommended species should be described, in some cases resulting in multiple filled in questionnaires per institution.
Other situations in which the recommended species are housed in a mixed species exhibit were searched for in the literature study, however only experiences from mixed situations in AZA institutions were found in an AZA Old World Monkey TAG mixed species manual (Strange, 2007).

2.3 Data collection

In order to collect the data required to answer the research questions two different collection methods have been used:

2.3.1 Literature study

During the search for experiences from previous researches on combining old world monkey species with other (old world monkey) species, the following search terms, always in combination with the term “old world monkeys”, were used (arranged in order of importance):

- *Cercopithecoidae*
- Mixed species exhibits
- Captivity
- Old World Monkey TAG
- Regional collection plan
- Husbandry guidelines
- International Zoo Yearbook

The major search engine during the research was Google (Google Scholar). On top of the information that was found by means of the regular search engines, literature from the WUR (Wageningen University and Research centre) library was used.
Additionally the EAZA and ISIS websites provided numbers of old world monkey living in captivity, and additional information from the Old World Monkey TAG.

2.3.2 Questionnaire

The questionnaire asks for experiences on several factors influencing the success of a mixed species exhibit with old world monkeys. (Appendix 1) For making the questionnaire suggestions from Zoo Research Guidelines (Plowman et al., 2006) were used. By using the answers from the AZA mixed species manual, information from Zoo Animals (Hosey et al., 2009), information from Wild Mammals in Captivity (Kleiman et al., 2010) and suggestions by the client T. ter Meulen (vice-chair Old World Monkey TAG) answers that could be expected from the questionnaire were formulated. These answers allowed the use of closed questions in the questionnaire, making answering take less time (important for the response rate) and processing these answers more efficient. For this same reason similar answers to open questions were afterwards put in categories.

3. Results

3.1 Old world monkeys in European institutions

According to the Old World Monkey TAG meeting of March 23rd 2011, 3023 TROWMs are kept in European institutions. (Figure 1) Population size ranges from 15 to 409 individuals per species. The different species are phylogenetically grouped together in the following genera: *Colobus (Col), Allenopithecus (All) , Miopithecus (Mio), Cercopithecus (Ccp), Theropithecus (The), Papio (Pap), Mandrillus (Man), Cercocebus (Ccb), Lophocebus (Lop), Macaca (Mac) and the Semnopithecus (Sem) and Trachypithecus (Tra).*

TAG Recommended Old World Monkeys
=
TROWMs

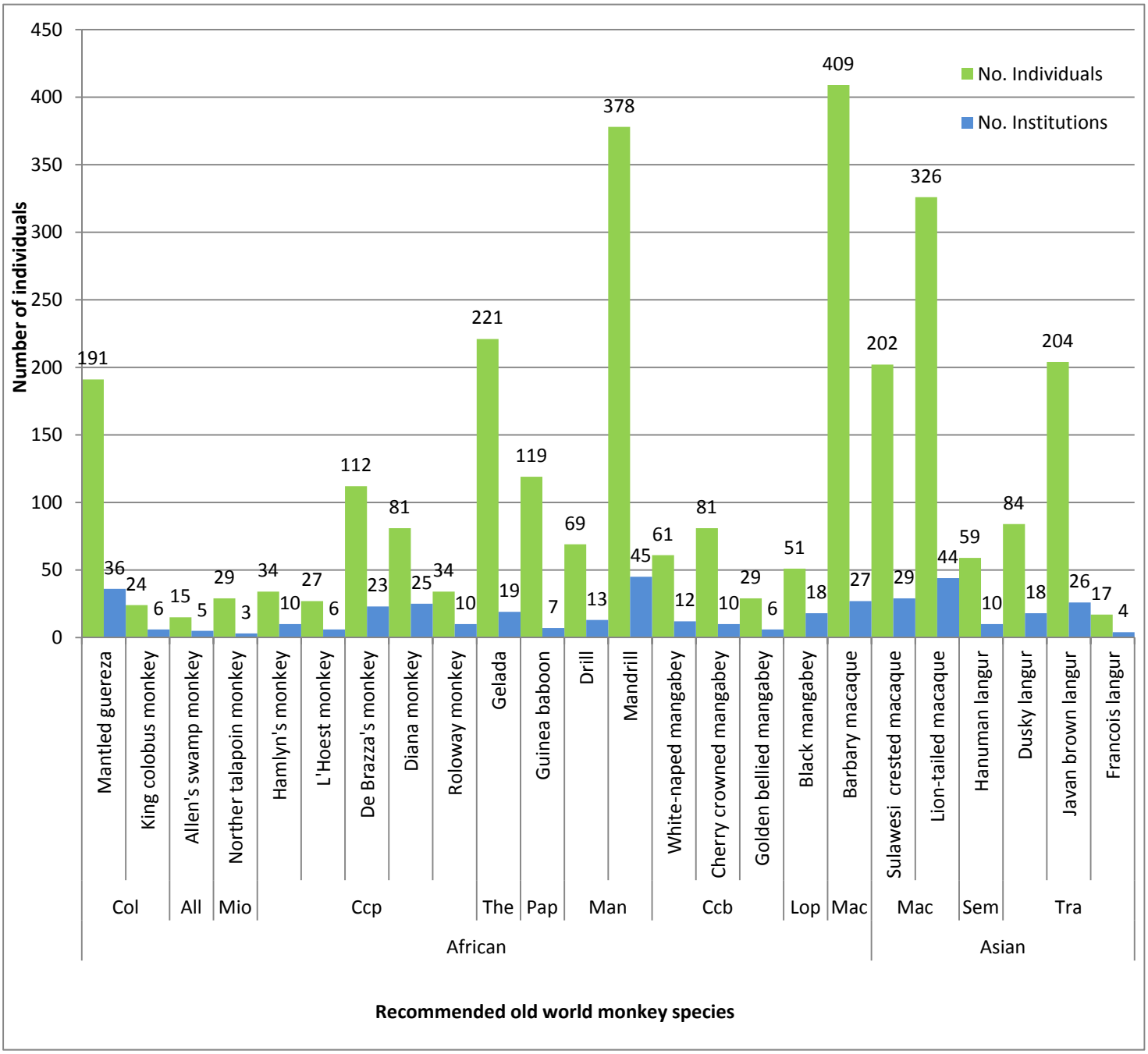

Figure 1: Number of individuals per TROWM species and numbers of institutions keeping them

Population sizes can vary between genera (i.e. *Macaca* has large population sizes, compared to *Cercopithecus*) and within genera (i.e. the big difference between mandrill and drill population sizes). (See also appendix 2)
A higher population number does not however mean that these species are more successful in captivity as the group composition should also be taken into account. In the wild most of the guenons live in small family groups, while macaques live in large social groups of about 50 individuals. (Rowe, 1996) With 81 individuals in 25 institutions compared to 409 individuals in 27 institutions the Diana monkeys are represented about as often in zoos as the barbary macaques (ISIS, 2011). They differ, however, in group size which in both captive species resembles the natural situation (Rowe, 1996).

Of the 24 recommended species 18 are African and 6 are Asian. The ratio of African versus Asian species in captivity therefore does not resemble the ratio in the wild (IUCN, 2011). (Table 3) In captivity there is a bias towards African species.

Table 3: Comparison wild and captive ratio African and Asian (TR)OWMs

	No. OWM subspecies in the wild	**No. OWM subspecies in captivity**	**No. TROWM subspecies in captivity**
African	144	67	18
Asian	140	31	6
Ratio Af/As	1:1	2:1	3:1

3.2 Old world monkeys in mixed exhibits

18 of the 40 institutions keeping old world monkeys in mixed species exhibits responded to the questionnaire that was sent to them. These 18 institutions provide information on 22 mixed species situations with TROWMs. Additionally, information on 49 mixed species situations with TROWMs were collected from the AZA mixed species manual, resulting in a total of 71 mixed species situations.

Of the 24 TAG recommended old world monkey species 20 are kept in mixed species exhibits.
The 20 TROWMs that have been combined, have been mixed with (1) other TROWMS (table 4), (2) non-recommended OWMs (table 5), as well as (3) other animal species (table 6).[1]

[1] Please note that of the 86 times a TROWM is mixed this is often done with more than one species. Therefore, in tables 4, 5 and 6 a total of 131 combinations is presented.

Table 4: Combinations of TROWMs with TROWMs

TROWMs / TROWMs	*Allenopithecus nigroviridus*	*Cercopithecus diana diana*	*Cercopithecus hamlyni*	*Cercopithecus neglectus*	*Colobus guereza*	*Macaca nigra nigra*	*Macaca silenus*	*Macaca sylvanus*	*Mandrillus leucophaeus*
Cercocebus atys lunulatus									
Colobus guereza					X				
Colobus polykomos									
Macaca silenus							X		
Macaca sylvanus								X	
Mandrillus leucophaeus									X
Mandrillus sphinx									
Miopithecus ogouensis									
Theropithecus gelada									

Table 5: Combinations of TROWMs with non-recommended (OW)Ms

TROWMs / Non-recommended (OW)Ms	*Cercocebus atys atys*	*Cercopithecus albogularis*	*Cercopithecus ascanius*	*Cercopithecus ascanius schmidti*	*Cercopithecus cephus*	*Cercopithecus lowei*	*Cercopithecus mitis stuhlmanni*	*Cercopithecus mona*	*Cercopitecus petaurista*	*Cercopithecus pogonias*	*Cercopithecus pygerythrus*	*Cercopithecus wolfi*	*Chlorocebus aethiops*	*Colobus angolensis palliates*	*Colobus guereza kikuyuensis*	*Erythrocebus patas*	*Gorilla spp.*	*Hylobates lar*	*Hylobates syndactylus*	*Lemur catta*	*Lophocebus albigena*	*Miopithecus talapoin*
Allenopithecus nigroviridus																						
Cercocebus atys lunulatus																						
Cercocebus torquatus																						
Cercopithecus diana diana																						
Cercopithecus hamlyni																						
Cercopithecus neglectus																						
Colobus guereza																						
Lophocebus aterrimus																						
Macaca nigra nigra																						
Macaca sylvanus																						
Mandrillus leucophaeus																						
Mandrillus sphinx																						
Miopithecus ogouensis																						
Trachypithecus obscurus																						

Table 6: Combinations of TROWMs with other animal species

TROWMs \ Other animal species	*Acryllium vulturinum*	*Alopochen aegyptiacus*	*Ammotragus lervia*	*Aonyx cinerea*	*Aquila chrysaetos*	*Arctictis binturong*	*Atelerix albiventris*	*Bucorrus abyssinicus*	*Bucorrus leadbeateri*	*Callosciurus prevosti*	*Capra ibex spp.*	*Caracara spp.*	*Cephalophus dorsalis*	*Choerpsis liberiensis*	*Coragyps atratus*	*Ephippiorhynchus senegalenis*	*Gyps fulvus*	*Hystrix cristata*	*Leptoptilos crumeniferus*	*Madoqua guentheri*	*Muntiacus reevesi*	*Numida meleagris*	*Oreotragus oreotragus*	*Orycteropus afer*	*Phacochoerus spp.*	*Potamochoerus porcus*	*Procavia capensis*	*Proteles cristatus*	*Rucervus duvaucelii*	*Suricatta suricatta*	*Tragelaphus euryceros*	*Tragelaphus spekii*	*Zalophus californianus*
Cercopithecus diana diana																		■				■		■			■	■		■			
Cercopithecus diana roloway							■																										
Cercopithecus neglectus													■														■						
Cercocebus atys lunulatus																									■								
Cercocebus torquatus														■																			
Colobus guereza	■							■	■				■	■		■		■		■			■		■	■	■	■			■		
Macaca nigra nigra				■																													■
Macaca silenus				■		■																											
Macaca sylvanus				■																													
Mandrillus leucophaeus		■												■																		■	
Mandrillus sphinx														■																			
Miopithecus ogouensis		■												■																			
Trachypithecus obscurus						■				■											■												
Semnopithecus entellus																														■			
Theropithecus gelada			■		■						■	■			■		■		■								■						■
Trachypithecus francoisi				■																													

Besides looking at the combinations of species, taking a more detailed look at these combinations might prove interesting. Therefore niche occupation, habitat and social structure were given a closer look as these are likely to be considered by zoos when mixing species and can provide information on what kind of species are mixable.

3.2.1 Combining species in terms of niche occupation

Using different layers of an enclosure might contribute to the success of mixed species exhibits. In that case it is relevant to look at which species are combined with the mostly arboreal or arboreal/terrestrial TROWMs. 90 out of 124 combinations contain at least one arboreal species. (Table 7) Combinations of arboreal and terrestrial species occur the most, but in most of the cases the terrestrial species are other animal species (i.e. duikers, hyraxes or porcupines) instead of monkey species.

Table 7: Combinations of species by niche

Species combination by niche	No. times combination occurred
Arboreal X arboreal	23
Arboreal X terrestrial	45
Terrestrial X terrestrial	7
Arboreal X arboreal/terrestrial	22
Terrestrial X arboreal/terrestrial	20
Arboreal/terrestrial X arboreal/terrestrial	7

3.2.2 Combining species in terms of habitat

All TROWMs live in forest habitats, except for the gelada which lives in open grasslands. It is therefore interesting to look at whether they have been mixed with other forest dwelling animals or not, in short whether zoos have mixed species based on habitat alikeness. Most of the combinations of TROWMs are indeed with other forest animals, however combinations of forest animals and animals that live in open land often occur as well. (Table 8)

Table 8: Combinations of species by habitat

Species combination by habitat	No. times combination occurred
Forest X forest	75
Forest X open land	27
Forest X water	7
Forest X rock	9
Open land X open land	8
Open land X water	1
Open land X rock	3

3.2.3 Social structure

Social structure between monkey species is variable as it ranges from monogamous pairs to big herds (Rowe, 1996). It is interesting to see whether these social structures have been recreated in captivity. In most situations this is not the case and the mixed situations do not represent the natural situation. (Table 9)

Table 9: Number of mixed situations with (un)natural TROWM social structure in captivity

Social structure	No. situations
Represents wild situation	28
Does not represent wild situation	50
Is unknown	8

3.3 Success and failure factors

Of the 71 reported combinations with TROWMs, 60 were considered successful and 11 were reported as a failure. Some species are mixed more often than others. With a frequency of 25[2] the colobus monkey is mixed over 3 times more often than any other species. (Table 10) The Diana monkey, De Brazza's monkey, mandrill and gelada also have relatively high combination frequencies compared to the other species. All species, except for the Hamlyn's monkey, have a higher success than failure percentage.

Table 10: TROWMs success percentage in mixed species exhibits

TROWM species	% success[3]
Allenopithecus nigroviridis	100 (n = 3)
Cercocebus atys lunulatus	100 (n = 4)
Cercocebus torquatus	100 (n = 2)
Cercopithecus diana diana	86 (n = 7)
Cercopithecus hamlyni	33 (n = 3)
Cercopithecus neglectus	71 (n = 7)
Cercopithecus diana roloway	100 (n = 1)
Colobus guereza	80 (n = 25)
Colobus polykomos	100 (n = 1)
Lophocebus atterimus	66 (n = 3)
Macaca nigra nigra	100 (n = 3)
Macaca silenus	100 (n = 2)
Macaca sylvanus	100 (n = 3)
Mandrillus leucophaeus	100 (n = 3)
Mandrillus sphinx	83 (n = 6)
Miopithecus ogouensis	100 (n = 2)
Semnopithecus entellus	100 (n = 1)
Theropithecus gelada	83 (n = 6)
Trachypithecus francoisi	100 (n = 1)
Trachypithecus obscurus	100 (n = 3)

Of the combinations of TROWMs the ones with "other animal species" occur the most, however combinations with non-recommended (OW)Ms are more successful. (Table 11) (See also appendix 3)

Table 11: Success percentage of combinations of TROWMS with TROWMs, non-recommended (OW)Ms and other animal species

Combination	% success
TROWM X TROWM	88 (n = 17)
TROWM X Non-recommended (OW)Ms	92 (n = 51)
TROWM X Other animal species	76 (n = 63)

[2] Please note that there are 71 combinations, however, as some TROWMs occur in the same combination the total number of times the species are combined is different (86).

[3] Please note that there are 60 combinations that were successful and 11 that were a failure, however, as some TROWMs occur in the same combination the total number of successes and failures are different (success: 73 and failure: 13).

3.3.1 Niche occupation and success

Whether the combined species are arboreal or terrestrial might have an influence on the success of a mixed situation. An example would be the combing of 2 tree-dwelling species, possibly causing conflicts as niches overlap or territorial behaviour occurs. The same might be the case in combining terrestrial species where lack of (vertical) escape possibilities can cause stress or conflicts. Therefore, it might be expected that these combinations should be avoided.
Earlier on it was mentioned that arboreal species occurred the most as almost all TROWMs were either arboreal or a combination of arboreal and terrestrial. Combining the TROWMs with other arboreal (monkey) species did not cause many problems. (Table 12)
The combination of an arboreal and a terrestrial species occurred the most, but a lot of these combinations failed. In almost all of them other non-primate species occurred.
In the other combinations failures were incidental. Species that are both arboreal and terrestrial did not cause many failures as it can be expected they can utilise the entire enclosure in the case of conflicts.

Table 12: Niche occupation and success percentage

Species combination by niche	% success
Arboreal X arboreal	87 (n =23)
Arboreal X terrestrial	64 (n = 45)
Terrestrial X terrestrial	71 (n = 7)
Arboreal X arboreal/terrestrial	95 (n = 22)
Terrestrial X arboreal/terrestrial	80 (n = 20)
Arboreal/terrestrial X arboreal/terrestrial	86 (n = 7)

3.3.2 Habitat and success

Looking at successes and failures for combinations of animals in different habitats, it shows that most are successful. (Table 13) Exceptions are when forest and rock animals are combined and when open land animals are combined.

Table 13: Habitat and success percentage

Species combination by habitat	% success
Forest X forest	89 (n = 75)
Forest X open land	81 (n = 27)
Forest X water	100 (n = 7)
Forest X rock	56 (n = 9)
Open land X open land	50 (n = 8)[4]
Open land X water	100 (n = 1)
Open land X rock	66 (n = 3)[4]

[4] In this case all failures can be contributed to one failed mixed species situation in which geladas were combined with 5 bird species.

3.3.3 Social structure and success

It is expected that the social structure of the TROWMs have an impact on the way the individuals of a species interact with one another and the species it is combined with. However, this impact does not show in the data as both situations that do represent the wild situations and does that do not have a high success percentage. (Table 14)

Table 14: Number of mixed situations with (un)natural TROWM social structure in captivity and success percentage

Social structure	% success
Represents wild situation	86 (n=28)
Does not represent wild situation	92 (n=50)
Is unknown	63 (n=8)

Having looked at these factors, there are more factors that are interesting when looking at mixed species exhibits, because they may have an influence on the outcome of them. These factors relate to group composition, the enclosure and management, and are described below.

3.3.4 Group composition

Species ratio

It is expected that a species with many individuals might be dominant/aggressive towards (a) species with fewer individuals. Therefore the species ratio (the number of individuals of a species relative to the number of individuals of the other species) is calculated for each mixed situation. The data is too varied between and within species (ratios vary from 1:1 to 9:1), as well as the success rates of the ratios, to find a significant trend. However, in only one case the ratio was reported to be critical in the failure of a mixed exhibit.

Age class

It was expected that young animals, being weaker and less experienced, would be a risk factor to a mixed situation. Therefore age class (young and adult) is researched per mixed exhibit. 27 mixed situations include young. 3 of these are unsuccessful, however in only one case the inexperience of a young animal was the cause for the termination of the mixed situation. It is also worth mentioning here that old age was reported as a factor for the success of two mixed situations, while in another situation old age was reported as a factor for the failure of the mixed situation. In one situation the young age of the animals at the time the species were introduced to each other and the mixed exhibit was considered crucial for its success.

Breeding

Breeding within a mixed situation was considered a potential risk as periods of sexual activity as well as protective parents can cause aggression. In 31 mixed situations breeding occurred and in nearly all situations young were raised successfully. Among these 31 situations with successful breeding, 6 were failed situations. So despite interspecific conflicts, successful breeding still occurred and breeding and raising of offspring were never the cause of the failure.

3.3.5 Enclosure

Size of the enclosure

The size of the enclosure was researched, as insufficient space for species to live in can be cause for conflicts. Here, as with species ratio, the data is too varied between and within species to find a significant trend (sizes vary from 40 geladas, combined with barbary sheep and rock hyraxes, in a 450m^2 enclosure compared to 2 Diana monkeys and 3 mantled guereza's in a 2000m^2 enclosure). However, 11 zoos have indicated sufficient space to be a critical factor for the success of a mixed

exhibit. Sufficient space is therefore one of the factors that zoos themselves have mentioned the most as critical factor.

Escape routes

Escape routes (enclosure related measures provided for individuals to get away from an aggressor/aggressors during conflict situations) in enclosures might prevent aggression between animals and were therefore researched. In 25 mixed situations escape routes are available. Only a few of these have failed. (Figure 2) Of the situations where no escape routes were applied most failed.

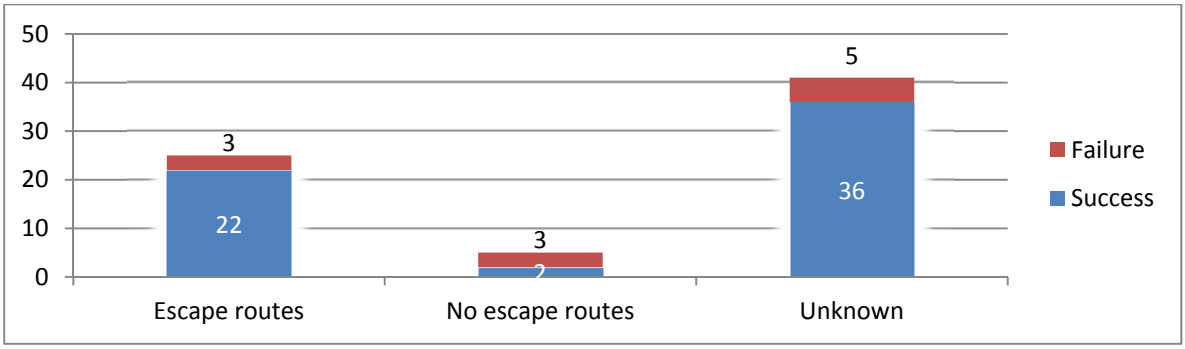

Figure 2: Number of mixed situations in which escape routes are (not) applied

3 different measures were researched on being present in the mixed exhibits: species specific spaces (places within an exhibit where only one species can come), height differences and multiple routes (providing several routes through an enclosure to avoid cornering). All measures are about equally used with some other measures mentioned as well, mostly these referred to a spacious and complex enclosure design. (Figure 3)

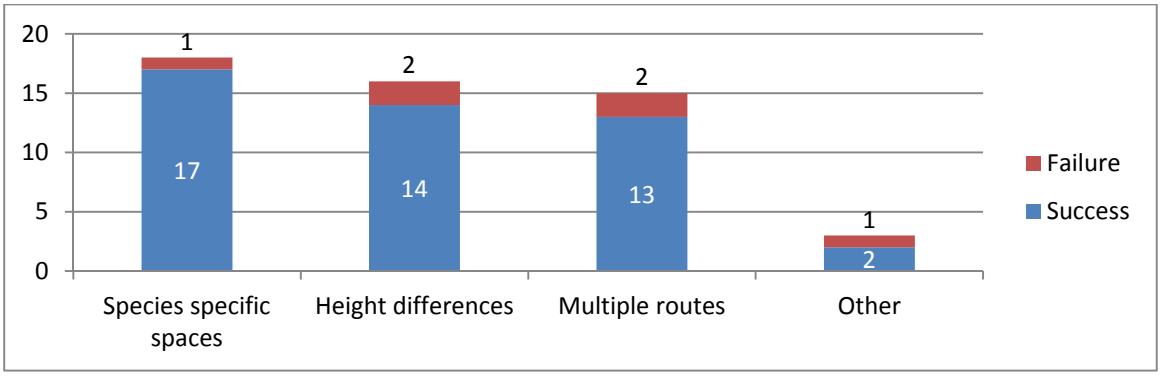

Figure 3: Number of times different escape routes were applied in mixed situations

5 zoos (that did not apply escape routes) have noted escape routes as a critical factor for the success of a mixed species situation.

Visual barriers

Visual barriers (those features in enclosure design that provide a chance of optical separation, allowing individuals to get out of sight of one another, thus avoiding possible conflicts) in enclosures might also prevent aggression between animals and were therefore researched as well. In 20 mixed situations visual barriers were present in the exhibit. (Figure 4) The high number of unknowns here is caused by the fact that the AZA mixed species manual did not provide information on this factor and therefore these situations were recorded as unknown.

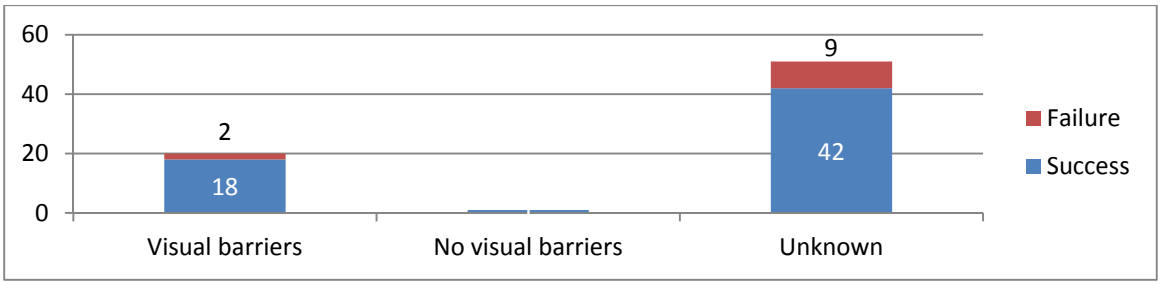

Figure 4: Number of mixed situations in which visual barriers are (not) applied

Four different features were researched on being present in the mixed exhibits: rocks, vegetation, elevation and palisade. Especially rocks, vegetation and elevation were used. (Figure 5) Other visual barriers were mostly trees and tree trunks.

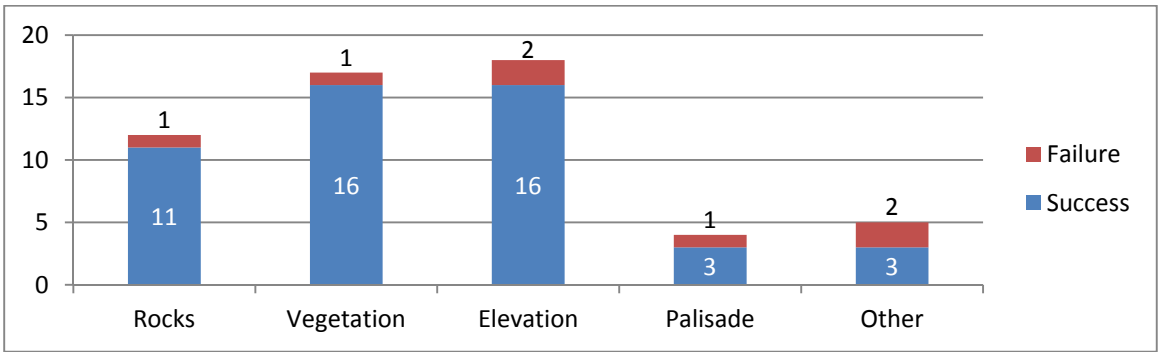

Figure 5: Number of times different visual barriers were applied in mixed situations

3.3.6 Management

Separation periods

Separation periods (any periods of time when species are separated from each other) are often applied to avoid aggression during "tense" times during which aggression is more likely to occur (i.e. feeding and oestrus). In 51 mixed situations species were separated during some time/part of the day. (Figure 6)

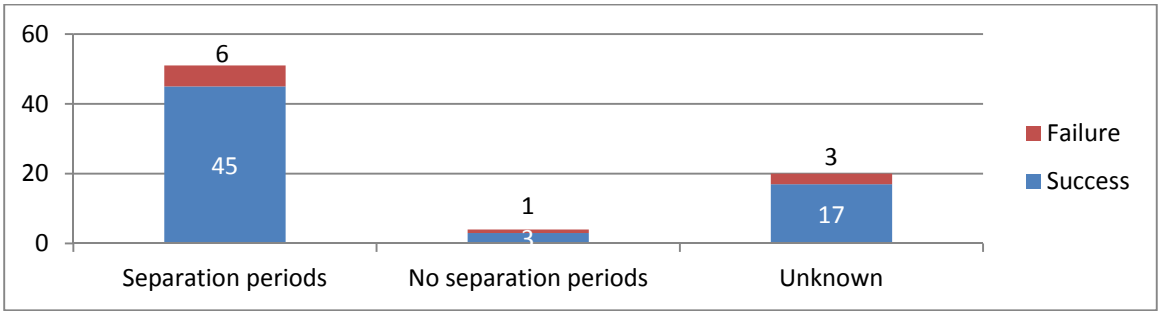

Figure 6: Number of mixed situations in which separation periods are (not) applied

4 different separation periods were researched on being applied in the mixed situations: feeding, night time, oestrus and raising of offspring. Separation mostly occurred during feeding and/or night time. (Figure 7) Other separation periods were during winter and bad weather, when the animals had to be moved inside where they were separated.

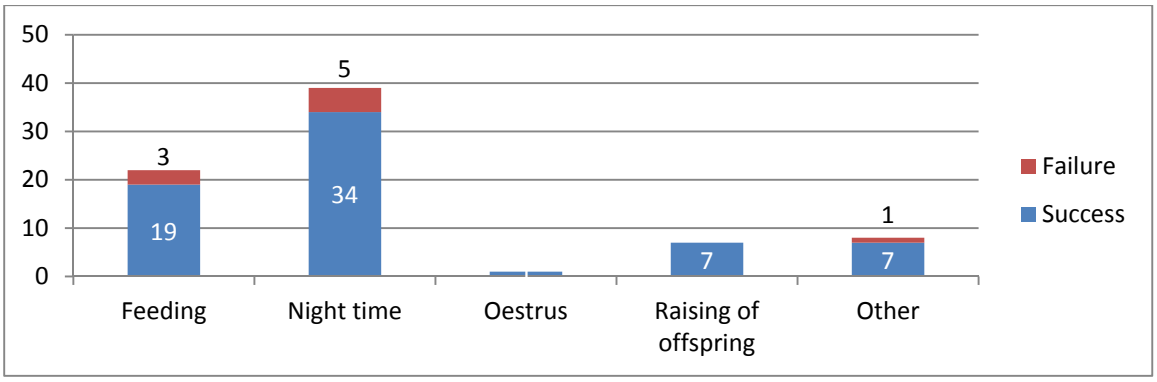

Figure 7: Number of times different separation periods were applied in mixed situations

Something to take into account here is that separation was applied in half of the failed situations. This being said it is probable that zoos apply separation periods as a means of preventing aggression, even if it is unknown whether aggression will occur: “better to be safe than sorry”.

Method of introduction

The method of introduction (of different species in a mixed exhibit) can be crucial as it can have a lasting effect on the outcome of the mixed situation. As the introduction of species in a mixed exhibit is a complicated process that is differently described by all involved institutions, methods have been divided into 12 different components that zoos have used. In total 60 methods of introduction were provided and methods included different sets of components. (Figure 8)

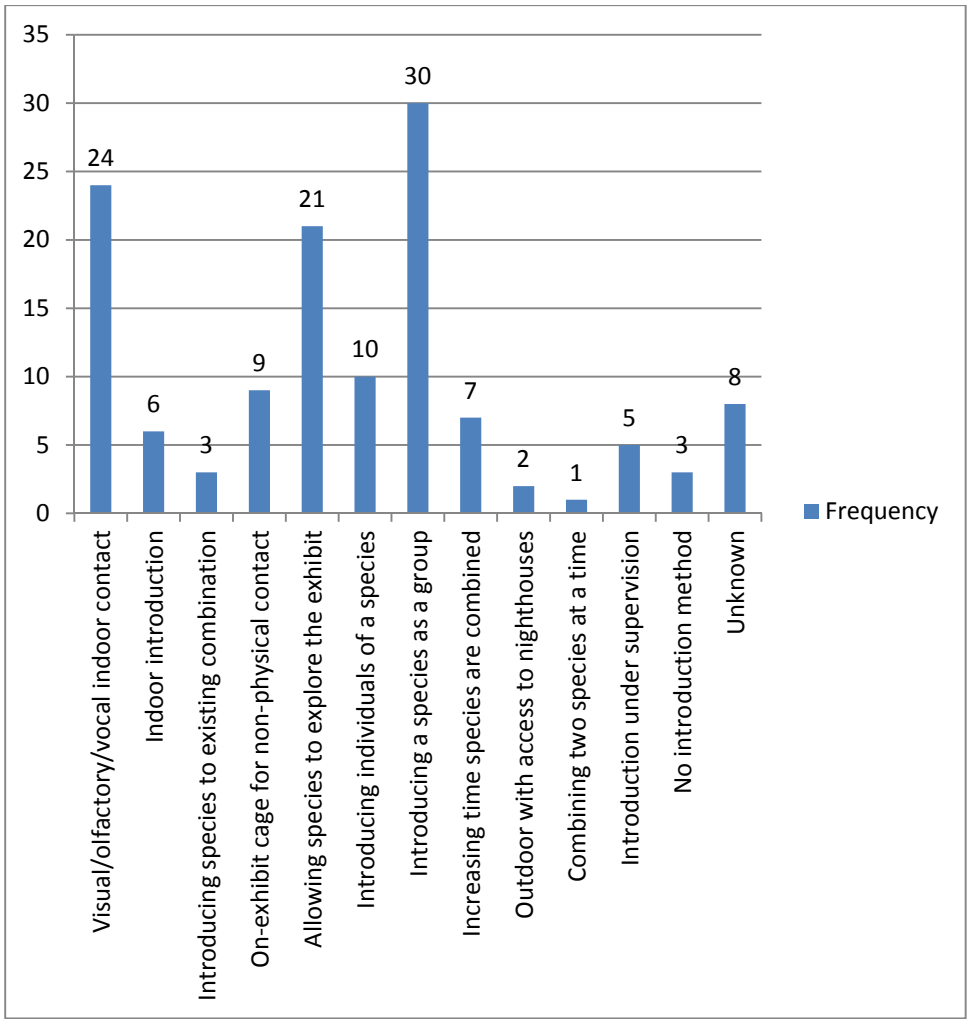

Figure 8: Frequency of methods applied during introductions

3.3.7 Critical factors as provided by the zoos

Finally, all zoos provided what they thought to be the critical factors influencing the outcome of a mixed situation. 25 factors were indicated of which escape routes, sufficient space, individual personality, species temperament and method of introduction were the most frequently mentioned ones. (Table 15)

Table 15: The 5 most frequently mentioned critical factors as indicated by the zoos

Critical factor	Frequency
Escape routes	17
Sufficient space	11
Individual personality	10
Species temperament	6
Method of introduction	5

Zoos indicated individual personality and species temperament frequently as critical for the success or failure of their mixed situation. Though often related to the success of a mixed situation, these two factors in all cases contributed to the failure of the mixed situation. Of the 11 failures, 5 were caused by the curious or bold behaviour of a TROWM and often the ineffective response of individuals of the other species to this behaviour. Often the mentioned behaviour was triggered in situations with smaller and/or nervous animal species (i.e. meerkats or storks). In 6 situations aggression, resulting in injury or death of individuals of the other species, was the cause of failure.

The TROWMs are in most cases the aggressors, only mixed with gorillas this was different and both species were aggressive. (See also appendix 4)

3.4 Intervention methods

Information on experience with intervention methods is minimal as only 2 institutions provided information on the applied intervention methods in a total of 4 situations. As there is only incidental information on intervention provided, no trend can be determined.
The reason for intervention was either aggression or conflict-based stress. In the case of aggression the use of a fire hose ended a conflict in which one juvenile drill was attacked by multiple adult barbary macaques. Stress (caused by interspecific non-aggressive interaction) was resolved by means of temporary separation of species until the peace was restored.

4. Discussion

The goal of this research, to provide information on the current status of the TAG recommended old world monkeys in zoos and insights in mixed species exhibits as a potential solution to the space issues for this taxon, has been achieved. Throughout this report a lot of information was provided on the status of old world monkeys in captivity and in mixed species exhibits. However, the overview of information from European zoos is not complete as less than 50% of the zoos responded to the questionnaire. With 60 out of 71 mixed situations being a success, mixed species exhibits are a valuable measure for solving the space issues for old world monkeys. This is supported by the AZA Old World Monkey TAG. The TAG states in its regional collection plan that it encourages zoos to mix species in order to solve the space issues for this taxon (McCann and Carter, 2008). The AZA regional collection plan for new world monkeys (*Callitrichidae*) (Desmoulins, 2006) illustrates this further by saying that because the new world monkeys are small and can be kept in mixed species exhibits there is no competition for space between the species of this taxon. Moreover, when managed properly and when selecting the right combinations of species, the potential disadvantages of mixed species exhibits are outweighed by the advantages (Kleiman et al., 2010).
The findings of this research correspond to the findings of the research done at CERZA, Lisieux (Pochon, 1998). At CERZA a group of mantled guerezas was kept together with a group of patas monkeys (*Erythrocebus patas*). Amongst Pochons findings was that the monkeys lived well together because they occupied different niches in the wild and the enclosure was adapted to this. The patas monkeys and mantled guerezas species were also separated at night. The advantages of the enclosure included an economical use of enclosure space and the release of enclosure space for housing other animals. Similar findings were obtained from the black mangabey studbook (Meulen, 2010), which includes a description about the situation at Gaiapark Kerkrade, the Netherlands, where black mangabeys are successfully mixed with gorillas. In this situation, separation was applied during night time, successful breeding occurred and enriching interspecific interaction was observed. The only problem occurred during the introduction of a male mangabey to the existing mixed situation. Due to the male's nervous personality it was not possible to properly introduce this individual. This matches the findings of this research which say that individual personality is an important factor to bear in mind when mixing species.

Some things to take into account when reading the results are:
Not all information asked for in the questionnaire was also available from the AZA mixed species manual. Some information like visual barriers was not clearly mentioned in the AZA mixed species manual and in these situations was therefore designated as unknown. This explains the fact that in the analysis of the critical factors the amount of unknown situations is sometimes high.
Though an indication was given of the percentage of success a species had in mixed situations, often this is accompanied by a small number of actual times they were combined. Therefore no definite indications can be given on whether a species does well in a mixed exhibit or not. For example the Hamlyn's monkey has only 33% success on its record, but it has only been mixed three times and therefore cannot be considered "uncombinable".
Something to consider when a mixed situation is reported as a success or a failure is how long the species have been mixed. There are many examples of mixed species exhibits that have worked successfully for many years and then suddenly broke down (Kleiman et al., 2010). This is also the case in this research. Most combinations were terminated within a short time (days to months), however the combination of a gelada with 5 bird species for example was reported as a failure but was together for 14 years. Therefore whether this is really a failure or a termination caused by an incident is questionable.

5. Conclusion

1) 19 of the 24 TROWMs have a higher success than failure percentage in mixed species exhibits. 12 of these even have a success percentage of 100. The L'Hoest monkey, golden bellied mangabey, Guinea baboon and Javan brown langur are not kept in mixed species exhibits. The Hamlyn's monkey is the only species which has a higher failure than success percentage in mixed exhibits.

2) 71 mixed situations were available to this research, consisting of a total of 131 combinations with TROWMS (every animal mixed with an TROWM counted separately, even though in the same exhibit). There were 17 combinations of TROWMs with TROWMs, 51 of TROWMs with non-recommended (OW)M species and 63 combinations of TROWMs with other animal species.

3) Of the 71 mixed situations, 60 were successful and 11 failed. For a successful mixed exhibit the following factors are important: sufficient space, the presence of escape routes, species temperament and personalities of the individuals. Niche occupation, habitat of the species in the wild, age and breeding seem to have no effect on the success of mixed exhibits. The effects of social structure, the presence of visual barriers in the exhibit and species ratio could not be indicated by this research. Different methods of introduction and separation periods were applied in most mixed situations. Though this research cannot say whether application of these is necessary for success, zoos have probably implemented them bearing in mind that it is "better to be safe than sorry".

4) Intervention was only described by two institutions. In one institution interspecific aggression occurred and this was resolved using a fire hose. In the other institution stress occurred and this was resolved by means of temporary separation of the species.

References

Literature

Baratay E. and Hardouin-Fugier E. (2002) Zoo, A history of zoological gardens in the west. Reaktion Books Ltd, London, UK.

Desmoulins, A. (2006) Regional Collection Plan for Callitrichidae (2nd ed.). Association of Zoos and Aquariums, USA.

Dollinger, P. (2006) WAZA: Understanding Animals and Protecting Them - About The World Zoo and Aquarium Conservation Strategy. WAZA, Bern, Switzerland.

Hosey, G., Melfi, V. and Pankhurst, S. (2009) Zoo Animals: Behaviour, Management and Welfare. Oxford University Press, Oxford, UK.

Kleiman, D.G., Thompson, K.V. and Baer, C.K. (2010) Wild Mammals in Captivity: Principles & Techniques for Zoo Management (2nd ed.). The University of Chicago Press, Chicago, USA.

McCann, C. and Carter, S. (2008) Old World Monkey Regional Collection Plan (3rd ed.). Association of Zoos and Aquariums, USA.

Meulen, T. ter (2010) Black Mangabey Studbook. Gaiapark Kerkrade, Kerkrade, The Netherlands.

Plowman, A. B., Hosey G. and Stevenson, M. (2006) Zoo Research Guidelines: Surveys and Questionnaires. BIAZA, London, UK.

Pochon, V. (1998) Mixed-species exhibit for Eastern black-and-white colobus and Patas monkeys at CERZA, Lisieux. *International Zoo Yearbook*. 36: 69-73.

Rowe, N. (1996) The Pictorial Guide to the Living Primates. Pogonias Press, Charlestown, UK.

Strange, D. (2007) Old World Monkey Taxon Advisory Group Mixed Species Manual (2nd ed.). Association of Zoos and Aquariums, USA.

Whitehead, P.F. and Jolly, C.J. (2000) Old World Monkeys. Cambridge University Press, Melbourne, Australia.

Internet

International Species Information System (ISIS) (2011) ISIS Species Holdings.
Available from: www.isis.org (Accessed February/March 2011)

International Union for the Conservation of Nature (IUCN) (2011) The IUCN Red List of Threatened Species. Available from: www.iucnredlist.org (accessed: February/March 2011)

Wilson, D.E. and Reeder, D.M. (2005) Mammal Species of the World: a Taxonomic and Geographic Reference (3rd ed.). Available from: www.bucknell.edu (Accessed February 2011)

Appendix 1: Questionnaire

Dear Sir/Madam,

First of all we would like to introduce ourselves. We are Elwin Kraaij and Patricia ter Maat, two students studying Animal Management at Van Hall Larenstein in Leeuwarden, the Netherlands. As our final thesis we are conducting a research on Old World Monkey species in Mixed Species Exhibits. Proposed by Tjerk ter Meulen (Vice chair of the OWM TAG and studbook keeper of Allen Swamp Monkeys and Black Mangabeys at Apenheul Primate Park, Apeldoorn the Netherlands), we were asked to look at experiences and opinions of zoos keeping Old World Monkey species in Mixed Species Exhibits. This will result in an overview of combinations that have worked in the past or are kept presently and factors that are possibly involved in the success of these combinations. The major reason for Tjerk ter Meulen to ask us to conduct this research was the fact that Mixed Species Exhibits have great potential as a husbandry measure. Some of the benefits are the possible enriching effect to the combined species, the unique education possibilities and making it possible to house more Old World Monkey species in European institutions.
The research will be on all Old World Monkey species, housed in combination with any other species (at present or in the recent past). We aim to include European zoos that house Old World Monkeys in this research by asking them to fill in a questionnaire. As your zoo currently keeps Old World Monkeys in Mixed Species Exhibits we would kindly like to ask you to fill in this questionnaire. Please find it below.
The final report of this research will be made available by the Old World Monkey TAG.

Thank you very much for your attention and we hope you will participate!

Kind regards,

Elwin Kraaij and Patricia ter Maat
Van Hall Larenstein & Apenheul

Questionnaire Mixed Species Exhibits with Old World Monkeys

Please return to sender (t.termeulen@apenheul.nl) before May 23rd.

- If a question is not applicable, do not fill in.
- Please tick multiple boxes when more than one answer applies to your situation.
- **Should there be multiple Mixed Species Exhibits with Old World Monkeys in your institution, please describe them in separate questionnaires.**

1. What is the name of your institution?

2. Please specify which Old World Monkey (sub)species are/were kept in this Mixed Species Exhibit:		
(Sub)species (Latin name):	Number of individuals (M.F.U):	Infant/Juvenile/Adult

3. What combinations of Old World Monkey (sub)species with other (Old World Monkey) species are kept?		
(Sub)species (Latin name):	(Sub)species (Latin name):	(Sub)species (Latin name):

4. Why has your institution decided to keep these species together?	
☐ Space issues	☐ Geographic realism
☐ Educational value	☐ Placement of bachelor groups
☐ Naturalness	☐ Behavioural complexity
☐ Enrichment	☐ Other:

5. How long have these species been kept together?	
☐ 0-3 months	☐ 2-5 years
☐ 3-6 months	☐ 5-10 years
☐ 6-12 months	☐ 10-20 years
☐ 1-2 years	☐ >20 years

6. If this term has ended, what was the reason?

- ☐ Fights
- ☐ Dominance/aggression of one species
- ☐ Interspecific predation
- ☐ Goal of Mixed situation has been achieved (for example temporary housing of a male group)
- ☐ Unsuitability of the enclosure (for example not enough places for a species to hide)
- ☐ No breeding success caused by the other species
- ☐ Change in group composition (births, deaths, maturation, acquisition, disposition)
- ☐ Personality of individuals
- ☐ Other:

7. Have any Old World Monkey species given birth during the Mixed Species situation?

If yes, which species have given birth?

(Sub)species:	Number of individuals (M.F.U):

If no, was this (possibly) related to the Mixed Species situation? ☐ Yes ☐ No

8. Have the young been raised successfully in the enclosure?

Has the majority reached their first year? ☐ Yes ☐ No
If not, what was the reason:

9. What are the general features of the exhibit where the species are kept (if applicable)?

Measurements (indoor):

(outdoor):

Type of fencing:
☐ Solid ☐ Partial ☐ Bars ☐ Netting and mesh ☐ Electric ☐ Glass ☐ (Dry) Moat
☐ Other:

Escape possibilities:
☐ Multiple routes ☐ Height differences ☐ Species specific spaces for the animals
☐ Other:

Visual barriers:
☐ Rocks ☐ Vegetation ☐ Elevation ☐ Palisade ☐ Other:

Separation periods:

☐ Feeding time ☐ Night time ☐ Oestrus ☐ Raising offspring ☐ Other:

Other relevant enclosure related information:

10. What benefits and/or problems did your institution experience with keeping the species in the Mixed Exhibit?

Benefits	Problems
Enclosure related:	Enclosure related:
Enrichment:	Fights:
Naturalness:	Dominance of one species:
Behavioural complexity:	Stress:
Visitors perception:	Visitors perception:
Other:	Other:

11. What was the method of introduction? Please be as detailed as possible.

12. How long did the introduction process take?

13. Did any intervention by the keepers take place during the Mixed Species situation? If yes...
What was the reason for intervention: What was the method of intervention: At what point did the decision for intervention take place: Did the intervention have the intended effect? ☐ Yes ☐ No How long did this effect last? Are you satisfied with the method of intervention? ☐ Yes ☐ No

14. Would you consider your Mixed Species Exhibit to be a success or a failure and why?

15. What were the most critical factors influencing the success or failure of your Mixed Species Exhibit?

Thank you very much for taking part!
Please send the filled in questionnaire to t.termeulen@apenheul.nl before May 23rd.

Appendix 2: TROWM Status

Common Name	Latin Name	No. TROWMs	No. Institutions	African/Asian	IUCN	EEP/ESB
Allen's swamp Monkey	*Allenopithecus nigroviridus*	5.10.0	5	African	LC	ESB
Diana monkey	*Cercopithecus diana diana*	32.47.2*	25*	African	VU	EEP
Hamlyn's monkey	*Cercopithecus hamlyni*	13.21.0*	10*	African	VU	EEP
L'Hoest's monkey	*Cercopithecus lhoesti*	14.12.1*	6*	African	VU	EEP
De Brazza's monkey	*Cercopithecus neglectus*	56.49.7	23	African	LC	ESB
Roloway monkey	*Cercopithecus diana roloway*	15.19.0*	10*	African	EN	EEP
White-naped mangabey	*Cercocebus atys lunulatus*	27.33.1	12	African	EN	EEP
Cherry crowned mangabey	*Cercocebus torquatus*	45.35.1	10	African	VU	ESB
Golden bellied mangabey	*Cercocebus chrysogaster*	11.18.0*	6*	African	DD	ESB
Mantled guereza	*Colobus guereza*	87.77.27*	36*	African	LC/VU	ESB
King colobus Monkey	*Colobus polykomos*	10.14.0	6	African	VU	EEP
Black mangabey	*Lophocebus aterrimus*	22.29.0	18	African	NT	ESB
Sulawesi crested macaque	*Macaca nigra nigra*	79.118.5*	29*	Asian	CR	EEP
Lion-tailed macaque	*Macaca silenus*	137.171.18	44	Asian	EN	EEP
Barbary macaque	*Macaca sylvanus*	184.190.35	27	African	EN	ESB
Drill	*Mandrillus leucophaeus*	32.37.0	13	African	EN	EEP
Mandrill	*Mandrillus sphinx*	140.234.4	45	African	VU	EEP
Northern talapoin monkey	*Miopithecus ogouensis*	18.11.0*	3**	African	LC	ESB
Guinea baboon	*Papio papio*	43.56.20**	7**	African	NT	ESB
Hanuman langur	*Semnopithecus entellus*	18.38.3**	10**	Asian	LC	ESB
Gelada	*Theropithecus gelada*	94.126.1	19	African	LC	EEP
Javan brown langur	*Trachypithecus auratus auratus*	68.128.8	26	Asian	VU	ESB
Francois' langur	*Trachypithecus francoisi*	6.11.0*	4*	Asian	EN	ESB
Dusky langur	*Trachypithecus obscurus*	63.14.7*	18*	Asian	NT	ESB

*Species status 2007 as provided by the Old World Monkey TAG

**Species status 2011 as obtained from the ISIS Species Holdings List

Appendix 3a: Combinations of TROWMs with TROWMs

Green: Success Yellow: Equal amount of successes and failures Red: Failure **Recommended OWM species**	**Recommended species**	*Allenopithecus nigroviridus*	*Cercopithecus diana diana*	*Cercopithecus hamlyni*	*Cercopithecus neglectus*	*Colobus guereza*	*Macaca nigra nigra*	*Macaca silenus*	*Macaca sylvanus*	*Mandrillus leucophaeus*
Cercocebus atys lunulatus				1	1					
Colobus guereza		1	1		1-1					
Colobus polykomos			1							
Macaca silenus							1			
Macaca sylvanus							1	1		
Mandrillus leucophaeus									1	
Mandrillus sphinx					1	2				1
Miopithecus ogouensis										1
Theropithecus gelada							1			

Appendix 3b: Combinations of TROWMs with other (OW)Ms

Green: Success
Yellow: Equal amount of successes and failures
Red: Failure

Recommended OWM species	**Other monkey species**	*Cercocebus atys atys*	*Cercopithecus albogularis*	*Cercopithecus ascanius*	*Cercopithecus ascanius schmidti*	*Cercopithecus cephus*	*Cercopithecus lowei*	*Cercopithecus mitis stuhlmanni*	*Cercopithecus mona*	*Cercopitecus petaurista*	*Cercopithecus pogonias*	*Cercopithecus pygerythrus*	*Cercopithecus wolfi*	*Chlorocebus aethiops*	*Colobus angolensis palliates*	*Colobus guereza kikuyuensis*	*Erythrocebus patas*	*Gorilla spp.*	*Hylobates lar*	*Hylobates syndactylus*	*Lemur catta*	*Lophocebus albigena*	*Miopithecus talapoin*
Allenopithecus nigroviridus			1		1			1															
Cercocebus atys lunulatus																		3					1
Cercocebus torquatus												1		1									
Cercopithecus diana diana																		1					
Cercopithecus hamlyni						1												2					
Cercopithecus neglectus																		3					
Colobus guereza		1	1	1				1			1		1					4			1	1	1- 1
Lophocebus aterrimus					1					1								1					
Macaca nigra nigra																		1					
Macaca sylvanus																	1			1			
Mandrillus leucophaeus							1		1								1						1
Mandrillus sphinx		1	1	1	1										1								1
Miopithecus ogouensis							1		1							1							1
Trachypithecus obscurus																			1				

Appendix 3c: Combinations of TROWMs with other animal species

Green: Success
Yellow: Equal amount of successes and failures
Red: Failure

Recommended OWM species	Other animal species	*Acryllium vulturinum*	*Alopochen aegyptiacus*	*Ammotragus lervia*	*Aonyx cinerea*	*Aquila chrysaetos*	*Arctictis binturong*	*Atelerix albiventris*	*Bucorrus abyssinicus*	*Bucorrus leadbeateri*	*Callosciurus prevosti*	*Capra ibex*	*Capra ibex nubiana*	*Caracara spp.*	*Cephalophus dorsalis*	*Choerpsis liberiensis*	*Coragyps atratus*	*Ephippiorhynchus senegalenis*	*Gyps fulvus*	*Hystrix cristata*	*Leptoptilos crumeniferus*	*Madoqua guentheri*	*Muntiacus reevesi*	*Numida meleagris*	*Oreotragus oreotragus*	*Orycteropus afer*	*Phacochoerus africanus*	*Phacochoeros aethiopicus*	*Potamochoerus porcus*	*Procavia capensis*	*Proteles cristatus*	*Rucervus duvaucelii*	*Suricatta suricatta*	*Tragelaphus euryceros*	*Tragelaphus spekii*	*Zalophus californianus*
Cercopithecus diana diana																				1				1		1				1	1		1			
Cercopithecus diana roloway								1																												
Cercopithecus neglectus															1										1					1						
Cercocebus atys lunulatus																										1										
Cercocebus torquatus																1																				
Colobus guereza		1							1	1					1	1		1		1		1			1			1	1	4-2	2			1		
Macaca nigra nigra					1																															1
Macaca silenus					1		1																													
Macaca sylvanus					1																															
Mandrillus leucophaeus			1													1																		1		
Mandrillus sphinx																2																				
Miopithecus ogouensis			1													1																		1		
Trachypithecus obscurus							1				1												2													
Semnopithecus entellus																																1				
Theropithecus gelada[5]				2		1						1	1	1			1		1		1									2						1
Trachypithecus francoisi					1																															

[5] All mentioned failures are part of one situation in which geladas were mixed with 5 bird species.

Appendix 4: Overview of failed mixed situations

Mixed species			Period of time together	Reason of termination	Critical factor
Diana monkey	Meerkat		2 years	Diana monkeys picking up and injuring the meerkats.	No escape routes
Black mangabey	Schmidt's red-tailed guenon		3 days	Mangabey chasing and slapping guenons (non-aggressive) eventually resulting in injury of one guenon.	Species temperament (skittish guenons)
Mantled guereza	De Brazza's monkey	Rock hyrax	Guereza & hyrax = 15 years + De Brazza during 3 years + Klipspringer during 1 year + Duiker during 4 years (Klipspringer & duiker were never together)	Aggression by all species, except for the duikers.	No species specific spaces Species temperament No hiding places from the public Enclosure unsuitability (too small)
Black-backed duiker	Klipspringer				
Mantled guereza	Rock hyrax		1 hour	Guereza chasing and grabbing the hyraxes; 1 juvenile hyrax got injured after 3-4 falls.	Enclosure unsuitability (high ledges causing injurious falls) Inexperience juvenile hyrax (could not escape from guerezas)
Mantled guereza	Rock hyrax		Short time	Female hyrax killed by guereza, after which male hyrax was removed.	Species temperament
Mantled guereza	Saddle billed stork		6 months	Guereza chasing storks	Species temperament (guereza: curious/aggressive – storks: nervous)
Mantled guereza	Talapoin monkey	Gunther's dik-dik	Guereza & dik-dik = 2 years + Talapoin during 2 months + Guineafowl during 5 months	Guereza picked on the talapoin and guineafowl	Species temperament No escape routes (cornering occurred)
Vulturine guineafowl					

Mandrill	De Brazza's monkey		A few days	Guenons constantly followed the mandrill, until mandrill did not dare go into the outdoor enclosure anymore.	Species temperament (curiousness/boldness of de brazza's) Species ratio (2 De Brazza's, 1 mandrill)
Hamlyn's monkey	Gorilla spp.		6-12 months	Fight in which all individuals were involved.	Species temperament Personality of 2 gorillas Unsuitability of the enclosure
White-naped mangabey	Hamlyn's monkey	Western lowland gorilla	2-5 years	Gorilla killed a Hamlyn's monkey.	Species temperament
Gelada	Black vulture	Griffon vulture	14 years	Geladas attacked griffon vulture	Species temperament (aggressive geladas)
Caracara	Golden eagle	Marabou stork			