Animals, zoos and conservation

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Contents

Foreword

Papers presented below emphasize the broad spectrum of studies on animals keeping in zoos to show some data of anatomy and morphology as well as problems of captive management and breeding under the light of species conservations, behavioural and genetic research and discussions about educational opportunities and optimalising the role of zoos in data collection, even protection of species and habitats found within zoo sites.

What makes the results in this volume worthy of attention then is that data collected from zoos are combined with conservation perspectives and present a great possibility to join research with practical work at zoo.

We hope that these different topics stimulate further interest in the field of research in zoos and help to identify promising areas for collaborative projects.

Editors

Conservation and captive management of Sumatran rhinos in Sabah, Malaysia

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Abstract: Captive management of highly endangered species becomes more and more important. However, information on the requirements of successful reproduction is often limited. The Sumatran rhino is one of the most threatened mammals. Only 300 Sumatran rhinos are left in the wild. The captive breeding of the species is not a story of success. Sumatran rhinos are solitary animals. They can fight viciously if the female is not sexually receptive. It is therefore important for captive management to identify the right time of mating. The purpose of the study is to determine whether a correlation exists between the female oestrus cycle and the behaviour of the rhinos. Data was collected between March 2004 and October 2005 from two captive Sumatran rhinos (1.1) kept in the Sumatran Rhino Breeding Centre in Sepilok, Sabah, Malaysia. We conducted regular hormone analysis using faecal samples. The rhinos were introduced regularly to each other through a fence and the time spend in contact was measured. We conducted regular behaviour observation, and we did daily temperature measurements. Progesterone analysis indicated that the female is still cycling but cycling activity is irregular. Our findings also suggest that male activity, such as erection and masturbation correlate with the female's cycling activity.

Key words: Sumatran rhino, reproduction, oestrus, behaviour

Captive management of highly endangered species becomes more and more important since large areas of natural habitat are rapidly dwindling. The management of captive animals requires knowledge of the basic requirements of a species and knowledge about its reproduction. However, this information is often lacking in highly endangered species (Wildt *et al.* 2003). The Sumatran rhino is one of the rarest and most threatened species in the world. It once occurred from the foothills of the Himalaya in Bhutan, through Burma, Thailand and Malaysia to Sumatra and Borneo (van Strien 1974). Today its distribution is limited to small numbers in Burma, Thailand, the Malaysian pensinsula and the islands of Sumatra and Borneo (Joubert 1996, van Strien

1974). Reasons for that are the age-long persecution for its horn and other remarkable parts and the disappearance of a large part of its habitat (Van Strien 1974).

The Sumatran rhino is the smallest of the five living species of rhinos. It was, and still is, one of the least studied and least known mammals in the world. Reasons for this are its elusive character, its rarity and the inhospitable nature of its habitat. Direct observation of the animal is almost impossible in the dense tropical forest and the study of indirect evidence is often the only feasible procedure (van Strien 1974).

Due to the lack of information captive breeding of the species was not a story of success. Since 1984, a total of 27 Sumatran rhinos were caught in the wild and brought to facilities throughout the world. Over a six year period, 29.6% of the Sumatran rhino died without contributing any genetic material towards the species' conservation (Abdullah *et al.* 1989). With time passing, people learned about the requirements of Sumatran rhinos in captivity and managed to keep the remaining animals alive. However, the next problem to be solved was how to breed the Sumatran rhino in captivity.

In captivity, male and female fight viciously if they are brought together while the female is not sexually receptive (Khan 1999). Due to this aggressive behaviour it is very important to identify the right time of mating. Hormone analyses have been used successfully to assist in the breeding of rhinos but there is disadvantage in their usage. The collection and processing of samples is costly and time consuming. For fast breeding decisions it is necessary to have other reproduction-associated characteristics which are easy to identify even for unskilled personal. Aim of our study was to establish whether rectal temperature and reproductive associated behaviour patterns correlate with faecal steroid hormones and can therefore be used to predict a forthcoming oestrus.

Material and methods

Data was collected between March 2005 and October 2005 from two captive Sumatran rhinos (1.1) kept in the Sumatran Rhino Breeding Centre in Sabah, Malaysia. The male is approx. 17 years old and the female is approx. 27 years of age. Both rhinos originate from the Kinabatangan area, in Sabah Borneo.

Faecal collection and hormone metabolite concentration in the faeces

A total of 102 faecal samples were collected from the 3rd of March until the 31st of October 2005, with one faecal sample every second day. Faecal samples were collected in the morning, either from the rectum of the animal, from the wallow in the enclosure, or from the ground of the night enclosure. The samples collected from the water and from the enclosure were from the night or the early morning and less than half a day old. The faeces were collected in a plastic bag, mixed and different parts of the dung were placed into a plastic tube. The tube was stored at 12°C until processing. The faecal hormone analyses were conducted in Vienna (see Kretzschmar *et al.*, in prep.).

Behaviour observations

The behaviour of the rhinos was monitored six days per week, from the first of March until the 31st of October 2005, resulting in 202 days of observation. The behaviour was monitored on an hourly basis, starting from 9:15 in the morning and finishing at five in the afternoon. Each animal was observed for 15 minutes per hour using focal animal sampling. The total time of observation was 287 hours and 15 minutes.

For 60 minutes each day, 30 minutes in the morning and 30 minutes in the afternoon, the animals were brought into a so called 'contact area'. In this enclosure the rhinos could get in direct contact to each other through a gate. The gate had vertical metal bars which allowed them to touch and lick each other. The animals were observed for 15 minutes each an 'contact area' was 199.69 minutes or 187 days.

Several behaviour categories were measured but only two categories were analysed in the study: the 'proportional duration of erection' and the 'proportional duration of contact'. The proportional duration of erection was established by measuring the length of an erection during a 15 minutes observation period using a stop watch. The length of time of all erections occurring within one day were added up and divided by the total length of observation for this day.

The proportional duration of contact between the male and female was established by measuring the length of time the animal spend in direct contact with each other while they were in the contact area. Direct contact was defined as an event starting when the animals touched each other through the gate with their mouth, ears, tongue etc., and stopped when one of them turned its had away and interrupted the contact. The length of time of all contacts in the contact area within one day were added up and divided by the total length of observation in the contact area during this day.

Body temperature

The temperature was measured early in the morning, three times per week from March until October 2005. It was measured in the rectum of the animal (until July 2005). In order to avoid variations in measurements in relation to the position of the thermometer the method was changed and a thermometer was placed in the faeces directly after collection. The difference between the two methods was 0.1^{O}C (median 1st method =36.3^{O}C, IQR=0.4^{O}C; median 2nd method=36.2^{O}C, IQR=0.5^{O}C).

Data analysis

Data are presented as median the interquartil range (IQR). To determine the time of oestrus, we used behavioural and endocrine criteria. The beginning of oestrus was identified by oestrogen values above the median oestrogen concentration plus IQR. The termination was determined by a decrease in concentrations below median concentrations plus IQR. Once the presence of a cycle was identified, we used behaviour patterns (see above) for verification.

Results

Figure 1

The female rhino did not cycle regularly (Fig. 1). She had a few clear oestrogen metabolite peaks which reached oestrogen metabolite concentrations of 2 ng/g faeces and above (on the 7th of March, the 23rd of March, the 7th of July and on the 15th of September) and she had a few less pronounced peaks which reach concentrations above

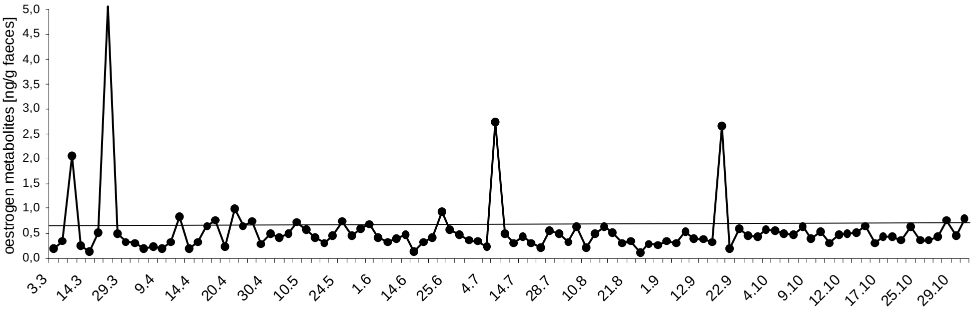

Fig. 1. Oestrogen metabolite profile of the female Sumatran rhino for the time period: March to October 2005. The horizontal line indicates the range of concentration which are above the median concentration plus the interquartil range

0.69 ng/g faeces (= median concentration plus IQR, see Table 1). The median length of the ovarian cycle, defined as the interval between successive oestrogen peaks was 16 days (IQR=10 days, n=11).

Table 1

Table 1: Oestrogen metabolite concentrations that reached concentrations above the median plus interquartil range

date	0estrogen metabolite concentration [ng/g faeces]
12. Apr. 05	0.83
16. Apr. 05	0.76
20. – 23. Apr. 05	0.75 – 0.99
7. May 05	0.73
24. May 05	0.74
21. June 05	0.93
28. Oct. 05	0.76
31. Oct. 05	0.79

Tanjung and Gelugob had frequent contact with each other while they were in the ‘contact area’. They had 14.5 days (median) per month direct contact with each other through the gate. During these days of contact, they spend 4.6% (median) of the time in the contact area in direct contact with each other. The number of erections per month was much lower compared to the number of direct contacts. The male Sumatran rhino had one erection per month (median=1, IQR=1.25). The median length of an erection was 2.8 minutes. Once it occurred, it took 3.9% (median) of the daily observation time.

Figure 2

There was a connection between the proportional duration of erections and the proportional duration of contacts: erections never occurred without direct contact between the animals and the longest proportional duration of erections occurred on days with the longest proportional duration of contact (Fig. 2). However, there were quite a few number of contacts were there were no erections.

Figure 3

Long lasting proportional contacts occurred on average two days (median, IQR=2) before oestrogen metabolite peaks occurred (Fig. 3) and the longest lasting proportional contact between the rhinos occurred two days before the highest concentration of oestrogen metabolites. This suggests a correlation between hormones and proportional

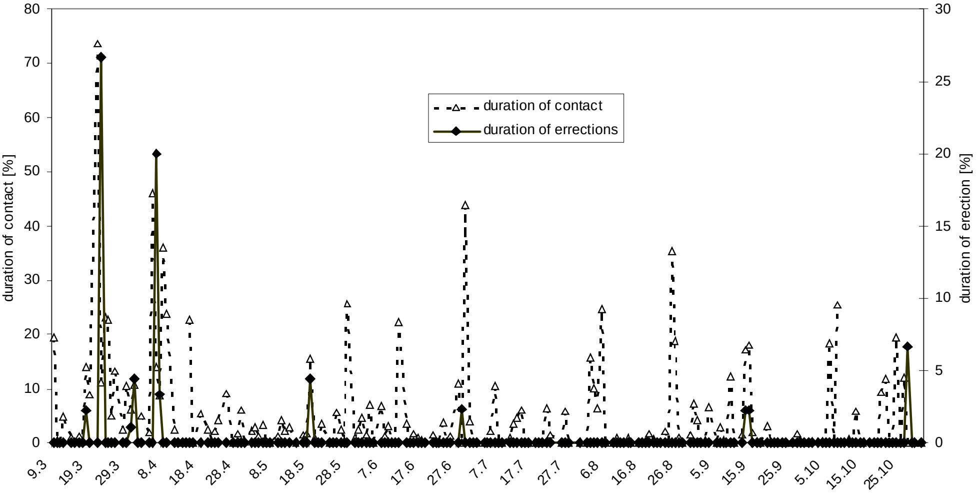

Fig. 2. Proportional duration of contact between the male and female Sumatran rhino in the contact area and the proportional duration of erections of the male rhino during the daily observation period from March until October 2005

duration of contact but there was often contact between the rhinos without any peak in oestrogen metabolite concentrations. In 69% of the days during which the rhinos had long lasting proportional contact (defined by the median proportional duration of contact plus IQR) with each other but no oestrogen metabolite peak occurred within the next 4 days following the contact.

Erections occurred on average 5 days (median, IQR=5) before an oestrogen metabolite peak occurred in the faeces and the longest lasting proportional erection per day occurred one day before the highest concentration of oestrogen metabolites

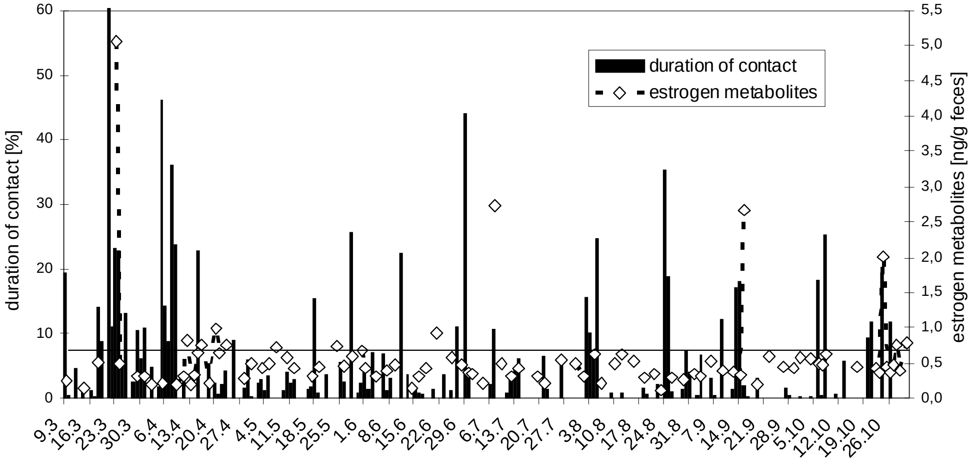

Fig. 3. The proportional duration of contact between the male and female Sumatran rhino and the concentration of oestrogen metabolites in the faeces of the female for the time period March to October 2005. The horizontal line indicates the range of concentration which are above the median concentration plus the interquartil range

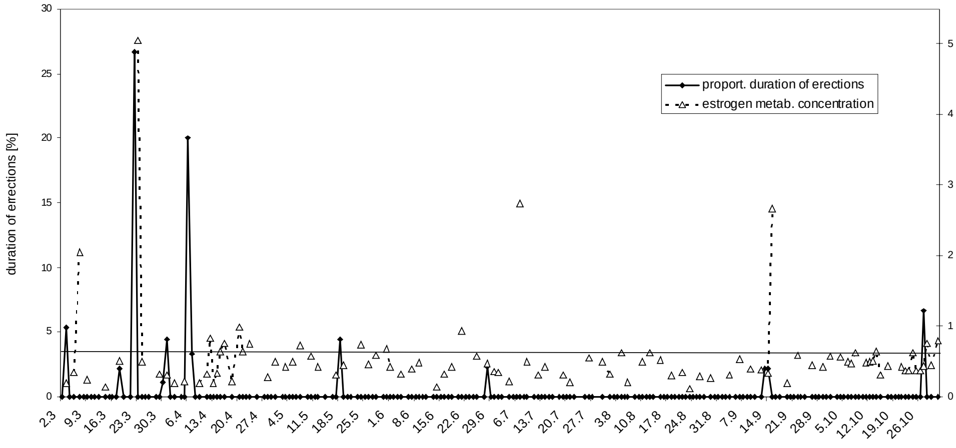

Fig. 4. Proportional duration of erection of the male Sumatran rhino and concentration of oestrogen metabolites in the faeces of the female for the time period March to October 2005. The horizontal line indicates the range of concentration which are above the median concentration plus the interquartil range

was measured (Fig. 4). Every oestrogen metabolite peak was preceded by an erection by 5 days, except in two cases, on the 7th of May and the 21st of June. However, in these two cases, erections occurred outside of the observation period which were not included in this analysis.

Figure 4

The median rectal temperature of Gelugob is 36.24°C; IQR = 0.4°C; n = 184). The temperature curve is characterized by a frequent rise and fall in temperature (Fig. 5).

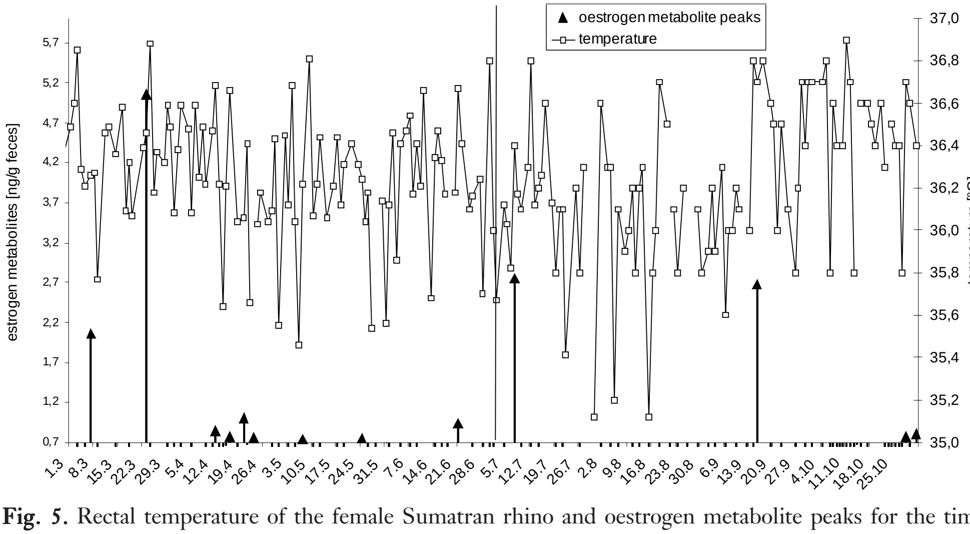

Fig. 5. Rectal temperature of the female Sumatran rhino and oestrogen metabolite peaks for the time period March to October 2005. The arrows give the date and concentration of oestrogen metabolite concentrations that are above 0,7 ng/g faeces. The vertical line indicates the beginning of a new measurement method to measure the temperature

Peak oestrogen concentrations occur during high and low temperatures measurements and are therefore not correlated with the rectal temperature.

Discussion

The study is using oestrogen metabolites to characterize the cycle of the Sumatran rhino. Oestrogen metabolites are not common for characterization of oestrus cycles in rhino species. However, Berkeley *et al.* (1997) found elevated faecal estrogens concentrations during the follicular phase of black rhinoceros and Schwarzenberger *et al.* (2000) used oestrogen metabolites as an indicator of the follicular phase. The objective of the study was to characterize long-term faecal oestrogen excretion in the Sumatran rhinoceros and to determine whether behaviour patterns and temperature can be used to predict oestrus. Faecal oestrogen analysis revealed that the female Sumatran rhino is cycling but cycling activity was irregular. The female had short oestrogen peaks of one or two days and she developed a median oestrous cycle length of 16 to 10 days. The cycle length is short in comparison to other cycles reported for Sumatran rhinos. Heistermann *et al.* (1998) reported a 25 day reproductive cycle for the Sumatran rhino and Roth *et al.* (2001) found a 21 day reproductive cycle. However, the cycle length in the present study was not regular. The longest interval between successive cycles measured was 70 days (occurring between July and September). The irregular cycle length is similar to the variations in cycle length reported for white rhinos. White rhinos develop cycle length from 4 to 10 weeks (Patton *et al.* 1999, Schwarzenberger *et al.* 1998) and the length varies among and within animals.

The identification of an approaching oestrous is very important for mating of Sumatran rhinos, since aggressive interactions between male and non-oestrous female often result in serious physical injury (Kahn *et al.* 1999). The irregular cycling activity of the female Sumatran rhino makes it very difficult to predict the upcoming oestrus. The identification of other factors helping to determine the periovulatory period is therefore very important. We measured the rectal temperature expecting that rectal temperatures would rise – in a similar way as in humans – just after ovulation when oestrogen concentrations decline. However, the study did not show any correlation between temperature measurements and oestrogen concentrations. A more promising alternative is the behaviour of the animals. Our findings show that there is a connection between the male and female behaviour, measured in frequency of contact and the frequency of erections and the oestrogen concentration of the female measured in her faeces. However, frequency of contact is not a reliable indicator of oestrus as high frequency of contact even occurred without any peak in oestrogen metabolites. This behaviour can not be used to plan introduction of the animals for mating. In too many cases the animals would be introduced to each other while the female is not in oestrus. The frequency of erections is a more reliable indicator of oestrus. Every time the male had an erection a median of 5 days later, an oestrogen metabolite peak occurred. An erection is also an easy recognizable behaviour which can be identified by unskilled personal. It is only necessary to monitor the animals on a regular basis. A few erections might be missed but once an erection has been detected it is likely that the female will come into oestrus and mating trials and introductions of the animals can be scheduled accordingly.

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Ex situ conservation of threatened primates and behavior: the case of the white-naped mangabey *Cercocebus atys lunulatus*

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Abstract: The white-naped mangabey *Cercocebus atys lunulatus* is a little-known semiterrestrial monkey endemic of the Western Upper Guinean Forest of West Africa, and it is listed as Critically Endangered by the IUCN. We shortly review available knowledge on socio-ecology of *Cercocebus* and results of captive breeding programmes, evidencing issues in the husbandry and management that need to be improved for the long-term viability of the captive population and its future utilization in reintroduction programmes.

Key words: The white-naped mangabey, ex situ conservation, captive population

An introduction to *Cercocebus*

After the splitting of some species of mangabeys (the '*albigena*' or arboreal group) to the genus *Lophocebus* (Groves, 1978), the genus *Cercocebus* now comprise seven allopatric taxa of unclear taxonomic status found from Senegal to the Congo River and, with two isolated populations, along the Tana River in Kenya and on the Udzungwa Mountains in Tanzania (Grubb *et al*., 2003; Jolly 2007). According to molecular data, semi-terrestrial monkeys of the genus *Cercocebus* are closely linked to *Mandrillus*, while arboreal *Lophocebus* form a clade with *Papio*, *Theropithecus* (Page et al., 1999) and the newly discovered *Rwengecebus* (Davenport *et al.*, 2006). Both *Mandrill* and *Cercocebus* are seasonal breeder (Jolly, 2007). Gestation is 170-180 days. In both genera an average of one infant is produced every two years (mandrills may have a higher reproductive success in captivity; Wickings & Dixson, 1992). *Cercocebus* is associated with riverine and swamp forest, a habitat that might represent a refuge from competition with the more recently evolved forest guenons (Kingdon, 1997). *Cercocebus* mangabeys forage mostly on the ground, specialising in fallen fruit, fungi, as well as invertebrates and vertebrates (Jolly, 2007). Cracking hard nuts has been associated with postcranial and dental features common to *Mandrillus* and *Cercocebus* (Fleagle & McGraw, 2002. *Cercocebus*, the less derived genus of the African Papionini subclade, seems to have larger home ranges and group size compared to arboreal *Lophocebus* mangabeys. Available evidence from *Cercocebus* taxa highlights a very complex social environment (Kinnaird, 1992; Range, 2006) characterised by multi-male, multi-female social groups and peaceful inter-group interactions in period of great fruit availability. Troops of 120 individuals in *C. atys atys* from the Taï N.P are reported (Range, 2006), while smaller group sizes are reported for other taxa; circa 25 for *C. torquatus* in Cameroon (Mitani, 1989), 20-60 in Equatorial Guinea (Jones & Sabater Pi, 1968); 7-18 for *C. agilis* in Gabon but with frequent exchange of individuals between 'bands' (Quris, 1975); 40 individuals for *C. sanjei* (Ehardt *et al.*, 2005). In the related *Mandrillus*, females live in group of 600-800 individuals (horde). Males are solitary and join the group during the 3 months breeding season (Abernethy *et al.*, 2002).

Three *Cercocebus* taxa are classified as Critically Endangered by IUCN, including *C. atys lunulatus*. All mangabeys are threatened due to their large size which makes them one of the most favoured target of hunters in African forests (i.e. Refish & Koné, 2005). *Cercocebus atys lunulatus* is one of the three taxa (the others are *Cebus xanthosternos* and *Pongo abeli*) included among the 25 most threatened primate taxa in the World (Mittermeier *et al.*, 2006) to have a potentially viable population in zoos world-wide. There is a captive population of about 60 individuals in European zoos plus Accra Zoo in Ghana, managed cooperatively through an European Breeding Program (EEP) (Abelló, 2004), while an unknown number of individuals is present in African zoos (i.e. Abidjian; Gippoliti pers. observ.). Considering the precarious status of this and other primate species endemic of the Western Upper Guinean centre of endemism (Ghana and Côte d'Ivoire east of the Sassandra River, cfr. McGraw, 2005), the creation and maintenance of a viable captive population of *Cercocebus atys lunulatus* seems a worthwhile conservation goal.

However, the possible effect of enclosure design and group size on the activity budgets, psychological well-being and breeding of captive white-naped mangabeys are still little understood. Although there is a good number of potential funders among European *Cercocebus atys lunulatus*, population size growth is slow (Abelló, 2004). Rome Zoo, for instance, breed the species from 1991 but for unknown reasons breeding rate has been low. Literature on captive *Cercocebus* appears greatly limited if compared to other Old World primate genera. A number of articles on the effects of several environmental variables on *Cercocebus chrysogaster* at the Sacramento Zoo were published by Mitchell and co-authors (Mitchell *et al*., 1987; 1988a,b; 1991a, b; 1992a,b). Biological and behavioural data on *Cercocebus atys atys* were collected at the large colony of the Yerkes Regional Primate Centre (Bernstein, 1976; Gust, 1995; Gust *et al.*, 1990). To our knowledge, only one paper had discussed the management and breeding of *Cercocebus atys lunulatus*, at the Jardin des Plantes in Paris (Schlee & Labejof, 1994), while Böer (1988) described the management of *Cercocebus torquatus* at Hannover Zoo. Socio-behavioral data on free-ranging *Cercocebus* are scarce (Quris, 1975; Kinnaird, 1992; Gust, 1994; Range & Noë, 2002, 2005; Range, 2006).

A behavioural approach to captive management

The need for behavioural studies to improve husbandry and management for breeding endangered species has been highlighted (Singh & Kaumanns, 2005). A number of primate populations managed through captive breeding programmes show far from satisfactory developments (Kaumanns *et al*., 1998/99). These last authors reported that despite apparently large populations for a number of EEP programmes, the effective (breeding) population size is indeed very small. This is due to few births per year in relation to number of adult females, high infant mortality, large differences in reproductive success between colonies, and a slow population growth, that finally, may result in a considerable loss of genetic variability in future generations. All this seems true also for the recently established *Cercocebus atys lunulatus* EEP, not included in the analysis of Kaumanns and collaborators (1998/99). It is reasonable to suppose that breeding and rearing failure in populations that are not limited by food availability or predators can only be traced back to factors such as behaviour and species-specific social organization (Singh & Kaumanns, 2005). In this regard, it should be highly advantageous to couple a psychological approach to investigate the origin and patterns of 'abnormal' behaviours (i.e. infant abuse and neglect, stereotypes) and of displacement activities (Maestripieri *et al.*, 1988), with an attempt to reproduce key environmental and social factors of the target species life-style in the wild.

It is clear that group sizes in European zoos are considerable smaller than those reported from the wild. Mangabeys have elaborated visual signals (tail position, white eyelids ecc.) to mediate aggressive and dominance situation in a complex society (Kinnaird, 1992). In zoos, the greatly impoverished social environment could encourage behavioral (mostly aggressive) interactions with visitors, with potential creation of a distressful situation for the mangabeys, and with further potential negative consequences for females reproductive physiology (Walker *et al.*, 2004). If key social features have to be incorporated in captive groups, it is also critical to add physical complexity to zoo environments, with particular attention to indoor areas. Actually, the rarity of serious direct aggression observed in the society of *Cercocebus atys* (Ehardt, 1988; Gust, 1995) may led to overlooking behavioral problems in captive mangabeys, as the frequency of stereotyped behavior recordered in the Rome group (Tami, 2002, Piedimonte 2006) or the still high neonatal abandonament and mortality recordered in European mangabeys and the Yerkes colony (cfr. Maestripieri *et al.*, 1997). This is a point needing more research. It could be expected that small captive units, and specifically females, may exhibit an high breeding potential due to reduced intrasexual competition (cf. Range & Noë, 2002), but this do not appear to be the case according to available data (Abelló, 2004). It must be said however that infant mortality and abandonament seems considerably high also in large groups (range 20-100 individuals) of *C. atys atys* held at the Yerkes Centre from 1969. Here there is a percentage of 7% of infant abuse and neglect (Maestripieri *et al.*, 1997), but also a similar percentage of stillbirths and a more than double percentuage of infant mortality for unknown cause, not including seven infanticide.

Infanticide related to acquisition of dominance by a new male is common; however aggression has been also reported by fathers of the infants under particular circumstances (Gust *et al*., 1995) and this phoenomen should be better investigate and understood given the obvious relevance to the viability of the captive population.

Future research

Following the result of recent researches on the social organization of *C. atys* in the wild, more attention should be put in creating and maintaining larger groups of females that are kin-related while eventually moving only males for genetic reasons.

The size of groups held in captivity should be enlarged, thus facilitating behavioral research on the species. However, to minimise situation of social stress, attention should be spent to create large and complex outdoor *and indoor* enclosures. Especially in continental climate zoos in fact, it should be important animals have enough space also when kept indoor in the bad season and during the night, and not only outdoor (Gippoliti, in press). As in the wild, it is important that subgroups and individuals have the possibility to separate for foraging on higly dispersed resources.

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How do you monitor rare and elusive mammals? Counting duikers in Kenya, Tanzania and Zimbabwe

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Abstract: Duikers (Cephalophini) are relatively small-bodied, predominantly forest dwelling African antelope. Monitoring duiker populations is difficult due to their cryptic nature and occurrence in often densely vegetated habitats. Yet, monitoring programmes are urgently required as many species are threatened by habitat loss and widespread hunting. Two case studies involving estimating population density or abundance for duiker species are presented here. Camera-trapping appeared to be the most effective relative abundance index in a pilot study to monitor Harvey's duiker in the Udzungwa Mountains, Tanzania. Line transect counts, tracking strips and hair-traps recorded fewer duiker events per replicate. Spoor presence was found to be an unreliable predictor of grey duiker density as estimated from dung heap counts in the Matobo Hills, Zimbabwe. Establishing reliable monitoring methods is a fundamental step for more detailed work with endangered duiker species.

Key words: Population density, relative abundance index, grey duiker, *Sylvicapra grimmia*, Harvey's duiker, *Cephalophus harveyi*, conservation

Introduction

The monitoring of rare and elusive mammal populations presents tremendous challenges to species conservation programmes. These challenges are encountered even with some of the best-studied mammalian faunas (e.g. Harris & Yalden 2004). Duikers (Cephalophini) are relatively small-bodied, predominantly forest dwelling African antelope. Monitoring of these species is hampered by their shy, solitary behaviour and occurrence in often densely vegetated habitats.

Population density estimation methods often used include line transect counts (Lannoy *et al.* 2003, Rovero & Marshall 2004, Struhsaker 1997), dung counts (Plumptre

& Harris 1995, Schmidt 1983) and drive counts using nets (Hart 2000, Noss 1998). However, all these methods have methodological problems and are often only appropriate in limited circumstances. In many cases a combination of different methods may be required (Bowland & Perrin 1994, Rovero & Marshall 2004). Furthermore, few studies have investigated possible relationships between density estimates and relative abundance indices such as spoor (tracks) or camera-trapping rates.

Many populations of forest antelope are under heavy pressure from habitat disturbance and hunting (Eaves 2000, Newing 2001). Duikers typically make up 40-60% of the meat available at bushmeat markets (Bowen-Jones 1998) and this trade is likely to be unsustainable in many areas (Fa, Yuste & Castelo 2000, Wilkie & Carpenter 1999). The number of small antelope taxa listed as threatened by IUCN is predicted to more than double by 2025 (East 1999). Reliable monitoring methods are crucial for assessing the conservation status of threatened duiker species and have important implications for sustainable management of hunted populations.

Paignton Zoo Environmental Park has been involved in duiker conservation and research projects in Africa since 1998. Many of these projects have involved efforts to estimate population density or relative abundance (Table 1). This paper describes two case studies that illustrate both the difficulty of monitoring duiker populations and the potential dangers in relying on one method without prior validation.

Table 1. Summary of methods used to estimate population density or relative abundance for duiker species during projects undertaken or funded by Paignton Zoo Environmental Park

Project area	Focal species	Territory-mapping	Dung counts	Line transect counts	Spoor counts	Hair-traps	Camera-traps	Drive counts	Reference
Matobo Hills, Zimbabwe	Grey duiker *Sylvicapra grimmia*	**	***	*	*				Lunt, Bowkett & Plowman *Unpubl. data.*
Udzungwa Mountains, Tanzania	Harvey's duiker *Cephalophus harveyi*		*	**	*	*	***		This study, Rovero & Marshall 2004.
Arabuko-Sokoke Forest, Kenya	Aders' duiker *Cephalophus adersi*		*	P		*	P	*	Kanga 2002, 2003, Schrodt 2005.

* – Not effective during pilot study, ** – Used to support other methods, *** Effective methods, P – Planned

Case study 1: A comparison of relative abundance indices for forest duiker: Harvey's duiker in the Udzungwa Mountains, Tanzania.

Rationale

Relative abundance indices can be useful for monitoring population trends when density estimates are very difficult or costly. A pilot study was conducted in the Mwanihana Forest, Udzungwa Mountains National Park to establish the most effective relative abundance index for Harvey's duiker.

Methods

Relative abundance was recorded along two 4 km transects using the methods outlined below. Details of sampling periods and number of replicates are given below for camera-trapping and in Table 2 for other methods.

Camera-trapping

Five heat and motion triggered cameras were placed singly at 0.5 km intervals along each transect between 1.75 km and 3.75 km. Cameras were not placed on the first 1.5 km of the transect due to the risk of theft. The sampling period was from 21/06-05/09/05 for Transect 1 and 20/06-30/08/05 for Transect 2. The number of trap-days varied between cameras (mean: 62, range: 44-79) due to effects of temporary malfunction and film and battery replacement. Specific locations were selected based on the presence of animal trails and spoor.

Line transect counts

Walks were carried out weekly during the sampling period. Transects were walked at approximately 1 km h-1 starting between 07:00 and 08:00. Animal-observer distances were estimated as part of a larger study to estimate population density but encounter-rates are reported here due to the small sample size.

Tracking strips

Established at 0.5 km intervals along each transect between 0.25 km and 3.75 km. Strips were 4 m x 0.5 m areas of damp sand placed on top of animal paths. During data collection strips were checked daily and antelope footprints were measured and assigned to a size-category – medium prints were assumed to belong to Harvey's duiker as sympatric forest antelope species are either much larger or much smaller.

Hair-traps

Established at 0.5 km intervals along each transect between 0.25 km and 3.75 km as for tracking strips. Each trap consisted of four plant stems (c.1-2 cm diameter) wrapped in sticky tape (sellotape) and suspended over an animal path at a fixed height. The outer two stems were set at 60 cm and the inner two at 40 cm. This arrangement allowed for taller antelope to leave hairs on the higher stems before they encountered the lower stems. Hair-traps were checked at the same time as tracking strips. Hairs were assigned to Harvey's duiker on the basis of colour and thickness.

Data analysis

In order to compare the effectiveness of different relative abundance indices, record frequency was calculated for each 0.5 km transect section by dividing the number of records for each species by the number of sampling replicates.

Results

Table 2. Sampling details and mean rates for Harvey's duiker for relative abundance indices used in the Udzungwa Mountains

RAI	Sampling periods	Replicates	Mean rate	Coefficient of variation (%CV)
Standard transect counts	26/06 – 05/09/05	10	0.11 km^{-1}	140.1
Tracking strips	12/09 – 11/10/05	10	0.75 day^{-1}	97.5
Hair-traps	12/09 – 11/10/05	10	0.25 day^{-1}	263.5

Camera-traps were the most effective duiker abundance index in terms of record frequency (mean records per trap-day: 0.16). Mean record frequency was low overall with one or less records per ten replicates for all other indices (Fig. 1). Coefficients of variation were high as would be expected from such small sample sizes (Table 2). Hair-traps were the least effective index.

Case study 2: The relationship between relative abundance and population density estimates: Grey duiker in the Matobo Hills, Zimbabwe.

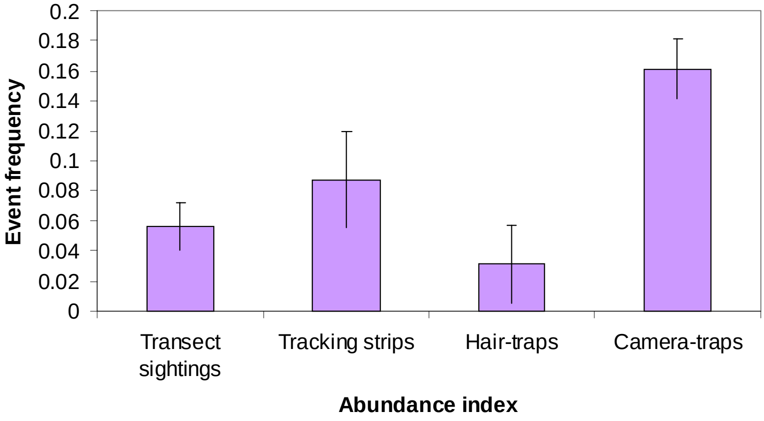

Fig. 1. Mean Harvey's duiker record frequency for relative abundance indices in the Udzungwa Mountains. Error bars are standard error. N = 16 (10 for camera-traps)

Rationale

For abundance indices to be useful as monitoring methods there should be a monotonic relationship between the index and actual density (Conroy 1996). Grey duiker population density was estimated between 2001 and 2006 in an area of the Matobo

National Park. Duiker spoor was also recorded as a relative abundance index. The relationship between the two measurements was tested to see whether spoor could be used to predict population density.

Methods

Duiker density was estimated using dung heap counts. Faecal deposits were counted in fifteen 1 km by 2 m strip plots each of which was divided into twenty equal sized subsections. Each plot was cleared of dung a known number of days before sampling. Plots were sampled fourteen times between 2001 and 2006. Animal densities were calculated for each transect for each sampling session using the formula (Boyce, 1995):

Where
D – density (animals km-2), X – no. pellet groups encountered, A – area sampled (km^2), T – time available for deposition (days) and R – daily defecation rate.

Dung pile deposition rates were calculated for both wet and dry seasons using locally held captive animals. Dung count density estimates were similar to population density inferred from radio-tracking (Lunt, Bowkett & Plowman In prep.).

The presence of grey duiker spoor in strip plot subsections was also recorded as an abundance index. A spoor index was calculated for each sampling session as the number of subsections containing spoor divided by the number of strip plots. The relationship between spoor index and duiker density overall and for wet and dry seasons separately was tested using Pearson correlation.

Results

There was no relationship between spoor index and population density overall (r=0.29, P=0.31, Fig. 2) or for either season considered separately (Wet season: r=0.60, P=0.15, Dry season: r=0.57, P=0.18). The two highest density points appear to be outliers; however, their exclusion does not affect the overall result (r=0.28, P=0.38).

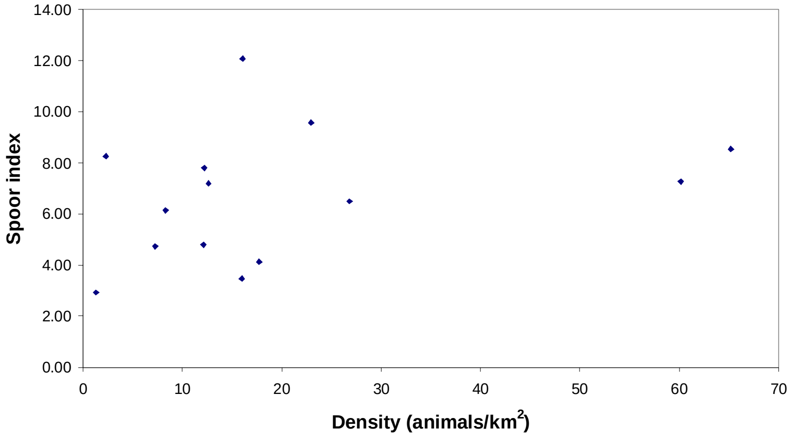

Fig. 2. Relationship between spoor index and population density based on dung counts for grey duiker in an area of the Matobo National Park, Zimbabwe

Discussion

In the Tanzanian case study the long-term comparative effectiveness of the various methods used cannot be evaluated due to the short study period and the small number of replicates. However, the intention of the study was to compare methods in the short-term for application to further monitoring efforts. Camera-trapping had the highest record frequency and therefore was the most efficient method in terms of detection. This is consistent with findings from a study that compared different methods for a range of mammals (Silveira *et al.* 2003) and with previous applications of camera-trapping to forest antelopes in the same study area (Rovero et al. 2005, F. Rovero unpublished data). Although the initial financial costs are high the cameras require far less time in the field than other methods and have the advantage that records are species-specific which may not be the case for tracking strips or dung counts. However, there are problems in interpreting camera-trap rates as an index of population abundance when animals are not individually recognisable. The relationship between camera-trap rate and actual population numbers requires further testing.

In the Zimbabwean case study the use of a relative abundance index did not prove useful in monitoring duiker population density. The lack of relationship between spoor and duiker density estimates means that it would not be possible to replace dung heap counts as a monitoring method with the less intensive spoor counts or to extrapolate density from spoor counts in new areas.

In most cases it is difficult to determine the value of a relative abundance index for duiker because the accuracy of any density estimate may also be questionable. In this case the dung heap count method makes several assumptions that may be violated in the field (Lunt, Bowkett & Plowman In prep.) although population densities were similar to published values for small antelope using different methods (e.g. Bowland & Perrin 1994, Plumptre & Harris 1995). In circumstances where it is not possible to validate monitoring methods a priori it is recommended that more than one method be employed in order to check for congruence between measurements.

Conclusions

- Relative abundance indices are useful for monitoring local duiker populations or for comparing abundance across similar sites. However, the optimal relative abundance index may vary with species and habitat.
- Short-term pilot studies can be useful in deciding which relative abundance methods to use when monitoring elusive mammals.
- For these relative abundance indices to be effective monitoring methods they should show a significant relationship with population density.
- Reliable monitoring methods are vital for ongoing projects with endangered duikers in East Africa. Further research, including camera-trap surveying, is planned for the little-known Abbott's duiker Cephalophus spadix in the Eastern Arc Mountains, Tanzania and the Critically Endangered Aders' duiker Cephalophus adersi in the coastal forests of Kenya.

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The influence of inbreeding on European bison sex ratio

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Abstract: In mammals the sex ratio at the moment of birth should be equal or close to one but there are different factors which could change this value. The ecological explanations of those factors are different, putting large enhance into mother social rank and conditions, sometimes expressed trough mother age or body weight. There is a few studies in which inbreeding influence is discussed. Last years within Lowland line of European bison was noticed some changes of sex ratio because more male were born. Within Lowland-Caucasian line of the species the proportion of males is more stable. The study considered inbreeding coefficient, mother age and year of birth as factors of changing the sex ratio. Based on data from Pedigree Book and using the logistic regression it was stated that inbreeding level has influence on the increase of males' proportion within Lowland European bison. The Lowland-Caucasian line does not show any relation between inbred and sex ratio.

Key words: The European bison, sex ratio, inbreeding level

Introduction

In last years increased proportion of born males was noticed in some Polish herds of Lowland European bison (*Bison bonasus bonasus*). The genetic variability of the species is very low because of bottleneck in the beginning of XX century. The species is divided into two genetically different lines Lowland (LB) and Lowland-Caucasian (LC) (Olech 1989, Pucek 1991). The level of inbreeding coefficient and genetic structure differ very much between those lines and according to IUCN Action Plan Lowland and Lowland-Caucasian lines must be separated in future breeding to prevent additional losses of genetic diversity (Pucek *et al.* 2004, Olech 1999).

The sex ratio is very important for breeding programs, especially in polygamic species where influence of female number is crucial for reproduction potential. In captive breeding program surplus males sometimes make problem and in consequence bachelor group must be organized. What could influence the offspring sex ratio – the question is interesting and very practical. On the question of adaptive variation of offspring sex ratio some researcher focused for years. The well known ecological model (TW) presented by Trivers and Willard (1973) suggested that for sexually dimorphic species high quality females (in high social rank) should produce more sons than daughters. Many studies supported this concept (Hewison and Gaillard 1999) but a lot of others have found lack or opposite influence of maternal quality into offspring sex ratio. According some authors good quality mothers should produce more often daughters than sons because females "inherit" social rank and home range of their mother but males generally disperse (Cote and Festa-Bianchet 2001). On the other side the local resource competition (LRC) hypothesis (Clark 1978) should biased offspring sex ratio toward the dispersing sex to avoid ecological competition with their offspring, so males should be preferred. The TW hypothesis considers sex ratios at the level of the individual while the LRC model is usually applied at the level of the population or species (Isaak *et al.* 2005). It is really difficult to measure the social value of females without long and difficult study but some authors noticed that there is great positive correlation between age and social rank of females. In captivity where small groups are kept in different condition it impossible to compare females' position from different groups, using age as an indicator seems to be very useful and simple. Cote and Festa-Bianchet (2001) proved for mountain goats that proportion of daughters decreased with female age from value around 70% to 25% but the relation between age and social rank was not proved.

The aim of this study was present the sex ratio within both lines (LB and LC) of European bison and analyze how mother's age and inbreeding value influence the sex ratio expressed as proportion of males born.

Material and methods

Material for analysis was the information about 6257 European bison born between 1946 and 2005 of known sex, mother's age and pedigree (1212 LB and 5045 LC) The data were gathered from International Pedigree Book for European bison. The inbreeding coefficient was calculated for every animal using own program based on Quass algorithm (Olech 2003). Animals were divided into three periods according to their birth year: first group for born before 1970, and last after 1990.

The influence of inbreeding level (F), mother's age (A) and period of birth (T_i) on offspring sex value (1 or 0) was calculated using logistic regression for binomial trait according to formula:

$$Sex = \frac{e^{\beta_0+\beta_1 F+\beta_2 A+\beta_{3i} T_i}}{1+e^{\beta_0+\beta_1 F+\beta_2 A+\beta_{3i} T_i}}$$

The value of regression coefficient β_1, β_2, β_{3i} explained the influence of factors into sex ratio measured by proportion of males because the value 1 was used for males and 0 for females. The parameters of logistic regression were estimated using the maximum likelihood method and significance of them were calculated using Wald test (SPSS 12.0).

Results

The proportion of males has been changed in years (Fig. 1). Usually the proportion of males within LB lines was lower than within LC line except last 10 years. The observed increase of males' proportion within Lowland (LB) line is large and can make some problem in the future. Generally within LB line the percentage of males is smaller than 50% and globally for whole analyzed period this difference from parity is significant (p=0.0183; $\div^{2}$ =5,57).

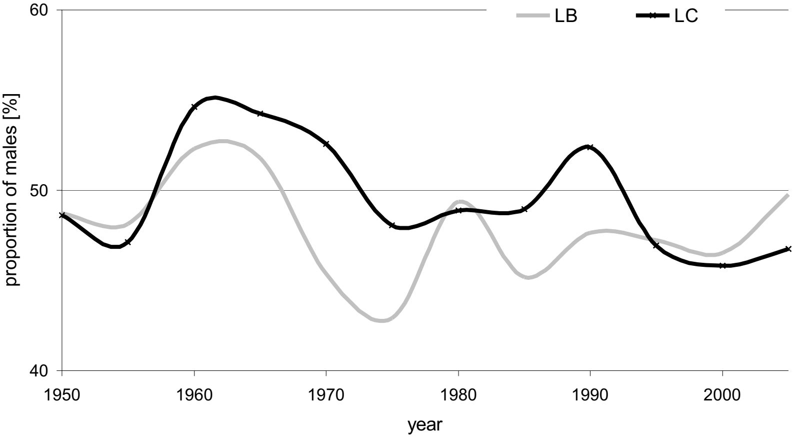

Fig. 1. Proportion of males born in years 1950-2005 within two lines of European bison: Lowland (LB) and Lowland-Caucasian line (LC)

The parameters obtained using the logistic regression are presented in table 1. The significant influence of birth period on males proportion was found and on the figure 1 those changes are visible. The most important is influence of inbreeding level on sex ratio within LB line. The increase of inbreeding coefficient would increase the percentage of males, so according to this model one could expect increase of males proportion because of continuous inbreeding grow. The influence of inbreeding on males' proportion within LC is very small and in the opposite direction – the increase of inbreeding level causes decrease of males percentage, but this relation is non

Table 1. The influence of mother's age, inbreeding coefficient and period of birth on males' proportion within two genetic lines Lowland (LB) and Lowland-Caucasian (LC) of European bison

Trait	LB line			LC line		
	Regression coefficient	Wald test	p-value	Regression coefficient	Wald test	p-value
Mother age	-0.017	1.263	0.261	0.005	0.452	0.502
Inbreeding level	1.051	4.614	**0.032**	-0.395	2.765	0.096
Time period		9.319	**0.009**		4.776	0.092

Table 2. The average value of inbreeding coefficient within every sex and genetic line

	LB line				LC line			
	males		females		males		females	
Period	N	F [%]	N	F [%]	N	F [%]	N	F [%]
up to1970	246	32.2	234	29.4	774	20.5	709	20.2
1970-90	219	39.6	280	38.7	1354	25.3	1337	25.7
after 1990	109	47.6	124	45.9	407	27.2	464	29.9

significant. In table 2 the average values of inbreeding coefficient for males and females are presented. It is possible to notice that average inbreeding coefficient for males from LB line is greater than for females but within the Lowland-Caucasian line this relation is in opposite direction in last period. Before 1990 the inbreeding value of males and females within LC line was equal. This comparison expressed also relation between inbreeding and sex-ratio. It is possible to explain that the noticed coincidence is not only random so it is possible that growing inbred level could cause changes in males proportion.

The influence of mothers age was not noticed for European bison. The only one difference is lower percentage of males born by mothers of age 11-15 years within Lowland line (LB). But this exception did not change the global lack of relation between age and sex ratio for the species. Within mountains goats the relation observed by Cote and Festa-Bianchet (2001) was very clear and there was proved that percentage of males increase with age of female.

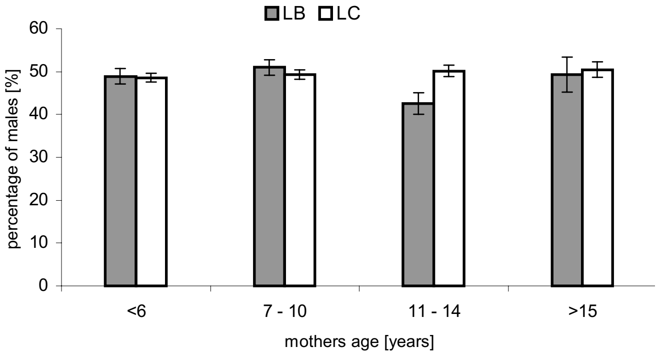

Fig. 2. The percentage of males depending of mothers age within two genetic lines of European bison

Conclusion

The sex ratio within Lowland (LB) line of European bison is skewed and under influence of inbreeding. Increase of inbreeding coefficient within captive population cause increase of males percentage. This kind of relation could make some problem in the future within this line because of smaller amount of females. According to logistic regression model the proportion of males increase in average of 0,25% for every percent increase of inbreeding coefficient. It would be difficult to explain these result using ecological models. It is possible that inbreeding depression cause some additional prenatal loses. The changes of males percentage within time is rather consequence of increase of inbreeding level than changes of environment. The influence of female age was not notice within European bison population. The study of sex ratio must be implemented into some large herds to include into discussion the social rank of female not only her age.

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How genetic monitoring is important in conservation?

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Abstract: The problem of inbreeding and its effect on animal's fecundity and viability was observed for years. In a small population the limited possibility of choosing breeding mate may cause exterior's defects, health problems, poor semen quality and other increase in inbreeding level on higher frequency. The same problem could be applied to small isolated population in the wild where exchange of genetic material is limited. In consequence of inbreeding and drift such small populations are weaker and extinct more frequent. The aim of this paper is comparison of different examples where inbreeding depression was observed and some activities for populations rescue were done. For this analysis three species of *Felidae* was chosen. They all have very serious decrease of genetic diversity and they suffer from inbreeding consequence. The first is well known problem of Florida panthers *Puma concolor coryi* and, second, similar one with Iberian lynx *Lynx pardinus* and as a third species Cheetahs *Acinonyx jubatus*. Population Viability Analyses (PVA) is the method of analysis where all factors that may cause species extinction are included. This kind of simulation can help in the effective management and protection endangered animal's population. The data for these analyses were taken from previous PVA. The analyses were made for 3 different levels of inbreeding depression with lethal equivalent equal to3,0; 3,4 and 4,0. In each of these levels two kind of simulation were done. First without assuming any loss of habitat and with 25% reduces of environment. According to analysis's inputs the population should persist over 100 years. For each of case 500 repeats was proceeded. Only once simulation was optimistic and resulted in 1,0 probability of persistence for the Florida panther population. Rest of the simulations predicted 0,970-0,998 probability of survival, beside it estimations with 25% loss of habitat shown bigger probability of extinctions for all levels of inbreeding depression.

Key words: conservation, endangered species, genetic, Population Viability Analyses, *Felidae*

Introduction

The inbreeding level and its effect on animal's fecundity and viability were observed for years. Previously this influence was studied within livestock and later such analyses were done for captive population of wild species. In a small inbreeded population where limited possibility of breeding mate choice may cause exterior's defects, health problems, poor semen quality and further increasing of inbreed coefficient.

The same problem could be applied to small isolated wild population where exchanging of genetic material is limited. In consequence of inbreeding and genetic drift the extinction of such small population is more probable.

The well known case of activities aiming at population rescue is history of Florida panther *Felis concolor coryi*. In later 1980s it was found that size of panther population is very small – about 50 individuals and in last years dropped down from ca 500 animals (Frankham 2002b). In this isolated population were found signs of inbreeding depression like: high frequency of cryptorchidism, sperm defects, kinked tail, "cow lick" patterns in their fur, cardiac defects (Frankham 2002a). Also infectious diseases were very frequent within this population. According to The World Conservation Union (IUCN) Florida panther is "Critically endangered" and the species is included in Appendix I of the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES).

The first Population Viability Analysis (PVA) - prediction of extinction for this species was made by Seal and Lacy (1989 after Frankham 2002a). According to their results Florida panther should extinct in 25-40 years because of inbreeding depression and demographic factors. The most important recommendations to save this species were: saving its habitat, starting with captive breeding program with planned further reintroduction (Frankham 2002b). Important part of captive breeding was plans of transferring large part of adult males in place that contained only females. That genetic management was very much needed because of extremely low level of genetic diversity within the species.

After some time it was stated that without expanding the gene pool of the species Florida panther will extinct very soon. The nearest panther from Texas *Felis concolor stanleyana* was chosen due to probably historical gene exchange with Florida population. The project, realized in 1995, assumed movement from Texas of 6-8 non pregnant females without any abnormalities observed in Florida's subspecies (Seal 1994). All 25 F_1 hybrids observed do not show "cow licks" or kinked tails symptoms. According to the next PVA made in 1999 Florida panther is no longer in the high risk of extinction (Maehr *et al*. 2001).

Cheetahs *Acinonyx jubatus* are the largest cat in the world. The population of this species in Africa counts less than 15.000 individuals and other 200 animals live in Asia (Marker-Kraus and Kraus 1997). The largest population of this species, ca 2500-3000 animals, exists in Namibia. Over 90% of this population exists outside the protected areas on commercial livestock/game farmland. The most important threats for cheetah are: loss of habitat, declining prey-base and competition with other large predators and farmer's interest. Cheetahs are blamed for more losses of livestock than they actually do. People practice "preventative management" by killing as many cheetahs as possible in any occasions and do not care that those cats are classified as protected (Marker-Kraus and Kraus 1997). According to IUCN Namibian's cheetah are "Vulnerable" and has been included in Appendix I (CITES).

The well known cheetah's high level of genetic homogeneity is a result from one severe bottleneck during the Pleistocene (about 8.000-20.000 years ago) (O'Brien *et al.* 1985). Due to this fact the genetic variability within the species is very low and animals are highly vulnerable to diseases. The survey of health made by Marker-Kraus (1997) for 250 individuals showed low condition of the species. For this survey many information like measurements and blood, skin samples from each animal were collected. The aim of this study was genetic monitoring as well as collection of information about health, virology, morphology and reproduction. Three morphological abnormalities were found: a distinct kink in tails (similar like in Florida Panther population) – the 19% of checked group, and two dental: focal palatine erosion (FPE) (16%), and crowed lower incisors (64%). The small genetic diversity and some health problems influence into further situation of the species.

The third chosen species is Iberian lynx *Lynx pardinus*, probably the most endangered cat in the world. This species exists only on Iberian Peninsula and the estimated wild population size is only around 100 adults. The captive population exists only in one reserve (Lloyd 2005). There are two isolated and unconnected metapopulations in Andalusia: first in Sierra Morena Mountains, second in Doňata National Park, and so far no individual has been moved between them (Godoy 2006). The size of those metapopulation is probably similar – in Doňata NP around 40-50 individuals (Johnson *et al*. 2004). This species is listed as "Critically endangered" in the IUCN Red List and classified on Appendix I of CITES.

The most important danger for lynx existence is: population fragmentation, sport hunting, fur collection, roads and intensive agriculture, and last which is crucial – decline of prey-base. The number of lynx depends on rabbit – their favorite pray. The catastrophic decline of rabbit population (70-90% of adult) caused by two diseases: myxomatosis and VHD had great influence into lynx situation. Actually the rate of rabbit population decline is smaller – around 30% per year (Lloyd 2005).

The Spanish Government is actually in the process of developing a national conservation effort for Iberian lynx. Genetic study (based on mtDNA) shown reduced genetic diversity and inbreeding accumulation within both populations, but especially in Doňata NP (Johnson *et al*. 2004; Godoy 2006). The results of different study are analyzed and some alternative scenarios are proposed. The study is aimed in explanation of the observed pattern and analysis in both populations how genetic drift played in recent times since isolation. Also some individually based simulations of demographic trends and extinction probabilities under a numerous of scenarios have been performed. Important is that up to now no evidence of inbreeding depression was found within this species. (Godoy 2006).

Material and methods

Population Viability Analyses (PVA) is the method of analysis where all factors that may cause species extinction are included. This kind of simulation can help in the effective management and protection endangered animal's population. The principle idea of developing the PVA is to assess the threats to population's survival probability and prevent against any danger before population's decline become inevitable. PVA estimates the likelihood of population's persistence in chosen time period of the future (very often during a hundred years). PVA requires the careful evaluation of input data like reproduction rates, genetic and demographic characteristic to obtain valuable results in process of computer simulations.

The most popular software for PVA is VORTEX (Lacy 1993) and the version VORTEX 9.60 was used for the purposes of this paper. The software simulates population size and structure through a series of events typical for life cycle of sexually reproducing wild animal population. The process is repeated many times to reveal the distribution of fates that the population might experience under a given set of input conditions. It is very important to prepare good input data based on proper information about the biology of population.

The results of a PVA should inform population managers what action should be undertaken to reduce threats to species persistence, such as change/save habitat, control invasive species, remove toxic substances, etc.

The data for these analyses were taken from previous PVA, the "Consensus" simulation made by Maehr *et al.* (2001). The analyses were made for 3 different levels of inbreeding depression measured by lethal equivalent equal to: 3,0; 3,4 and 4,0. In each of these levels two kind of simulation were done. First without assuming any loss of habitat and second with 25% reduces of environment. According to analysis goals the population should persist over 100 years. For each of case 500 repeats were proceeded. Due to lack of gene diversity, another simulation for this population was done. Changes of heterozygosity caused by habitat carrying capacity increase were presented by Maehr *et al.* (2001). Using in this paper "Consensus" parameters taken from that study the analysis were made with three levels of inbreeding depression and without t assuming loosing of habitat.

In this paper only PVA for panthers was done due to accessibility of complete data. The information for Iberian lynx PVA (Gaona *et al.* 1998) has not been sufficient and the parameters for cheetah in Namibia were not published.

Results and discussion

Only once simulation was optimistic and resulted in 1,0 probability of persistence for the Florida panther population (Table 1.) It was the case with the smallest inbreeding depression and no change in habitat. Rest of the simulations predicted 0,970-0,998 probability of survival, beside it estimations with 25% loss of habitat shown larger probability of extinction for all levels of inbreeding depression. In every PVA's the population didn't reach the habitat carrying capacity of 70 individuals. Assuming level of lethal equivalent 4,0 and lost of environment the situation of panther's is the worst with prediction of 85 years to extinction. In general, options without loosing a space are much better, but it's rather improbable that this habitat hasn't been changed for next 100 years (Fig. 1 and Fig. 2.).

The carrying capacity increase showed positive correlation on gene diversity for all analyzed inbreeding influences (Tab. 2.) but only population of 400 individuals could assure heterozygosity higher than 90% in every level of inbreeding depression.

Table 1. Comparison of Florida panther's PVA results

Outputs	Level of inbreeding depression					
	3,0	3,4	4,0	+ 25% loss of habitat		
				3,0	3,4	4,0
Genetic diversity	0,690	0,684	0,687	0,609	0,613	0,613
Probability of persisting 100 years	1,0	0,998	0,998	0,986	0,982	0,970
Final population mean size	63,56	63,17	61,98	44,93	43,5	41,45
Mean time to extinction [years]	-	95	92	89,43	84	84,87

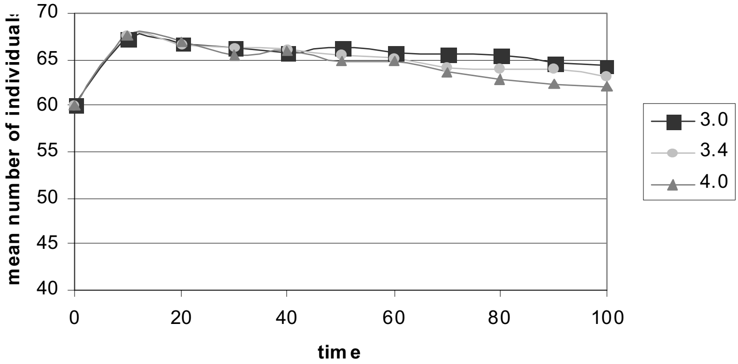

Fig. 1. The size of Florida panther population under influence of inbreeding depression with different value of lethal equivalent

In 1989 Seal and Lacy made first Population Viability Analysis for Florida panther. That results shown very big risk of extinction in 25-40 years (Frankham 2002b).

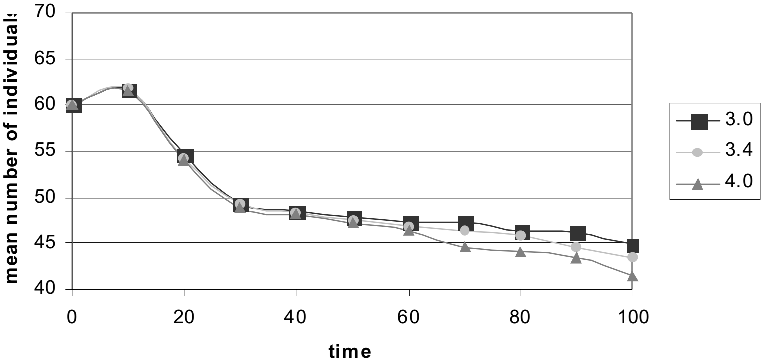

Fig. 2. The size of Florida panther population under influence of inbreeding depression with different value of lethal equivalent and 25% of habitat loss

Their recommendation was captive breeding. Subsequent PVA's results were very much under influence of used demographic parameters and in all the time frame were 100 years (Maehr *et al.* 2001). The data used by Maehr *et al.* (2001) are probably the best because of long study results. According to their results there was no risk of

Table 2. Changes in genetic diversity level caused by carrying capacity increase

Carrying Capacity	Level of inbreeding depression		
	3,0	3,4	4,0
70	0,6903	0,6843	0,6869
100	0,7681	0,7689	0,7726
150	0,8344	0,8352	0,8316
200	0,8646	0,8652	0,8620
250	0,8846	0,8852	0,8870
300	0,8956	0,8992	0,8990
350	0,9089	0,8993	0,8990
400	0,9146	0,9001	0,9006

Florida panther's extinction. Results of this paper are similar to them only in one case, the most optimistic; but mean final population was lover, although inbreeding depression was assumed to be smaller.

In both analyses increasing habitat carrying capacity resulted in increasing gene diversity, without any regard of inbreeding depression level.

Many different organizations cooperate to find the best solution for rescue the population. Florida Game and Fresh Water Fish Commission with Conservation Breeding Specialist Group of the SSC/IUCN made a workshop and try to prepare a plan for genetic restoration and management of this species, named "Florida Panther Recovery Plan" (Seal 1994). The plan determined the criteria for young females imported from Texas. It also noticed the need of monitoring demographic and fitness parameters and the role of captive management.

The viability and probability of Iberian lynx extinction was studied in several populations separately (Gaona *et al.* 1998). Some of the demographic parameters were problematic to estimate and were chosen on the base of other medium size cat species like e.g. bobcat. The result of Gaona *et al.* (1998) analysis was that the metapopulation could extinct within 100 years. In case of increased carrying capacity, what means habitat protection, the result was more optimistic so the population of lynxes should sustain.

The aim to start Captive Breeding Program (CBP) for lynx was protection from extinction. Within this program information about both sanitary and reproductive data are collected as well as the possible occurrence of inbreeding depression can be tested. The goal of CBP is *in situ* conservation support through further restocking or reintroduction (Godoy 2006). The IUCN/SSC Cat Specialist Group, together with its Spanish, Portuguese and international partners maintains a network to support the preservation of the Iberian lynx

The most important goals of the established in 1990 Cheetah Conservation Fund CCF are long-term conservation, research and education. The Fund initiated a management plan beneficial for both – cheetahs and farmers and prepared for farmers education programs concentrating on livestock losses reduction. The next aim is the continuation of biological material collection for development cheetah's data base. Also some recommendations for captive program for this species are needed, especially because 90% of all cheetahs in world's Zoos originate from Namibia.

Conclusions

In each of presented species protection of their habitat and captive breeding program were recommended. In wild population also reintroductions could help in improving demographic and genetic situation. Although gene pool is similar within captive and wild population, the gene frequency differs and relationship between them is smaller after several years of captive breeding. For every species some NGO were established by people involved to help in managing population or cooperate with existing organizations to protect species.

It is important to use the best and the most current data for Population Viability Analysis because results are more precise and more valuable for population managers, who can react before situation would get worse if predictions are pessimistic. It is worth to run PVA from time to time with more precise inputs data. Using PVA several different scenarios can be used to have the best knowledge about what might happened to population.

In every closed or isolated population, no matter in the wild or captivity, physical and genetic welfare of animals is important. Having pedigree it is obvious that genetic situation and inbred coefficient are monitoring. Also in the wild populations, without control of origin, those factors should be monitored to prevent any physical abnormalities that might occur as the result of inbreed depression. Simulation with VORTEX using demographic information is being used as a tool for prediction both – demographic and genetic future of population. In animal conservation it is important to work on each aspect of species' protection and concentrate not only on habitat's saving and on education but also on monitoring the current genetic situation of population.

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Methods of fennecs *(Fennecus zerda)* keeping in European zoos

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Abstract: Fennecs *(Fennecus zerda)* have been exhibited in European zoos for about 150 years. Now fennecs are exhibited in 37 zoos, the number of these animals being kept in zoos is around 100. We can observe the decline of births in European zoos. This smallest fox of the world not seams to be difficult for keeping in the zoo. Since 2003 fennec management data have been collected in 25 European zoos. The subject of research has referred to: dimension and different aspects of enclosures, enclosure's enrichment, feeding and characteristic of fennecs' behaviour in every zoo. Due to multiple methods of fennecs keeping and a small number of observations in the group, statistic analyzes of results couldn't be done. The main goal of this research is to find tendencies which could show the best conditions for keeping and breeding this species in zoos. Obtained data shows that fennecs breed better in zoos which don't keep them in the nocturnal houses, but assure them free access to the outdoor enclosures. The method of feeding shows influence on the fennecs' reproduction in captivity. Zoos which breed fennecs supply them with much diversified food. Also a good contact with the keepers is proved to have positive influence on fennecs' reproduction.

Key words: fennec fox *(Fennecus zerda)*, captive population, husbandry

Introduction

In the wild the Fennec fox *(Fennecus zerda)*,the smallest fox of the world, can be found in the desert area of North Africa, throughout Sahara, including Marocco, Algeria, Tunisia, Libya, Egypt and Sudan (Grzimek 1979; Sillero-Zubiri *et al.* 2004). Due to the mostly nocturnal activity, small size and non research into this species biology and status in the wild is very few known (Gauthier – Pilters 1967). Fennec fox is listed by CITES as Appendix II. In the IUCN Red List is reported as insufficiently known species, but suspected to be threatened (Ginsberg and Macdonald 1990).

This species has been exhibited in European Zoos since the end of XIX century. Probably first Fennec foxes have been kept in Paris Menagerie de Jardin de Plantes (year 1851), but first complete data is from London ZOO from 1929. At the beginning zoo population was based on fennecs donated by private people who had kept them as pets (Mekarska 2001). In order to control size and genetics of this population European Association of Zoos and Aquaria has established Fennec Fox European Studbook in 2001. In 2004 Fennec foxes were exhibited in 37 European Zoos. European captive population size amounts about 100 animals (Mekarska 2004). This species not seams to be difficult for keeping in zoo conditions, but problems with reproduction, especially with rearing rates of puppies, are observed (Gangloff 1972; Weiher 1976; Mekarska 2004). This is an indicator of poor or inappropriate welfare conditions (Broom 1988). For that reason research on methods of fennecs keeping and its influence on reproduction have been done.

Material and methods

Methods of fennecs keeping has been examined in 25 European zoos. The subject of research has referred to: dimension and different aspects of enclosures, enclosure's enrichment, feeding and characteristic of fennecs' behaviour in every zoo. All those aspects have been analyzed referring to breeding results (data from Fennec Fox European Studbook containing 780 animals)

Due to multiple methods of fennecs keeping and a small number of observations in the group, statistic analyzes of results couldn't be done. The main goal of this research was to find tendencies which could show the best conditions for keeping and breeding this species in zoos.

Results

Enclosures for fennecs in European zoos

There are two types of enclosures in European zoos: fennecs are keeping only in the indoor enclosures (in 6 of 25 zoos) or they have the access to the outdoor enclosures (in 19 of 25 zoos). 80% zoos breeding fennecs are giving them access to the outdoor enclosure. In the group of zoos not breeding fennecs this percentage is lower (70%).

Mean surface of outdoor enclosure is significantly higher in the group of zoos breeding this species (40 m^2) than in the group of zoos not breeding this species (21,7 m^2). The difference in the surface of the indoor enclosure is not so significant and amounts 10,7 m^2 in zoos breeding fennecs and 12,6 m^2 in zoos not breeding fennecs.

For fennecs enclosure's enrichments zoos generally use sand, rocks and woods on the floor, caves and nesting boxes for breeding purposes and food hidden in boxes to increase activity of the animals. The enrichment practices differ so much in zoos that it is impossible to set in order it and compare with zoos breeding or not breeding fennecs.

Fennecs diet:

Typical fennecs diet in European zoo consists of: meat (beef, chicken and whole mice, rats, one-day-old chickens, mealworms, insects), dog's or cat's pallets, cheese, eggs, biscuits, honey, boiled rice, fruit and vegetables. Zoos which breed fennecs replace meat with mealworms, insects, mice (fennecs' food in the wild) and give them much more diversified food.

Behaviour

In 9 of 12 zoos breeding fennecs, which have responded as for behaviour, fennecs don't react to the visitors. In group of zoos not breeding fennecs (3 zoos has responded) in 2 of 3, fennecs don't react to the visitors.

In 10 of 12 zoos (83,33%) breeding fennecs the animals are on friendly terms with their keepers. In the group of zoos not breeding fennecs this percentage is lower and amounts only 44,44%.

In 11 of 17 zoos (64,70%) breeding fennecs, which have described fennecs daily activity, the animals are active during the day. In group of zoos not breeding fennecs this percentage is lower and amounts only 33,33%.

Discussion

Even Fennec foxes are reported to be nocturnal in the wild (Gauthier-Pilters 1967) in zoo conditions they are much more comfortable in the outdoor enclosures than in the nocturnal houses. This can be caused by several factors: in the outdoor enclosures the animals have more space, more hidden places and they are less exposed to the stress caused by the noise made by the visitors and the keepers. These results are similar to research comparing the influence of environmental conditions on stereotypic behaviour of Fennec foxes in USA (Carlstead 1991).

Fennec foxes are omnivores in the wild. They hunt for insects, small rodents and birds, lizards, they also eat eggs, fruit and some tubers (Sillero-Zubiri *et al.* 2004). The diet offered in European zoos is very similar to Fennecs natural food. The consumption of alive insects influences to two positive aspects for animals: digestive and behavioural (when eating leaving insects).

Behavioural studies in this research have been based on short questionnaire only (no systematic behavioural observations had been done). Number of answers is not sophisticated, but they confirm that Fennecs foxes breed better when they are not exposed to the stress (caused by the indoor enclosure's conditions, noise made by the keepers and the visitors).

Because there are multiple stress factors which can influence fennecs' reproduction in the captivity, for example a quality of a contact with a keeper, neighbourhood of other species, research on this subject will be continued. The main target is to publish husbandry guidelines in the near future to help zoos in breeding fennecs.

Conclusions

As in the case of many canid species, also problems in reproduction caused by stress are common in captive Fennec foxes population.

Fennecs breed better in zoos which don't keep them in the nocturnal houses, but assure them free access to the outdoor enclosures. Zoos which breed fennecs supply them with much diversified and “natural” food. A good contact with the keepers is proved to have positive influence on fennecs' reproduction.

Acknowledgements. I would like to thank the various people who have helped collect this information in all 25 zoos: Zoo d'Amneville, Amsterdam Zoo, Antwerp Zoo, Brno Zoo, Chomutov Zoo, Dubai Wildlife Center, Dvur Kralove Zoo, Gdansk Zoo, Hannover Zoo, Heidelberg Zoo, Kaliningrad

Zoo, Karlsruhe Zoo, Krakow Zoo, Zoo de La Fleche, Zoo de La Palmyre, Landau Zoo, Lisbon Zoo, Nikolaev Zoo, Novosibirsk Zoo, Praha Zoo, Riga Zoo, Stuttgart Zoo, Suffolk Zoo, Ueckermunde Zoo and Wroclaw Zoo.

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Recruitment of young into the working caste in Damaraland mole-rats, *Cryptomys damarensis*, and its influence on other colony members

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Abstract: The eusocial rodents *Cryptomys damarensis* display a division of labor into frequent and infrequent workers; the division (caste) often being related to an individual's size. This study focuses on the recruitment of young into the working caste, particularly on the predestination of caste, developmental differences within a litter, first work attempts of pups, and the litter's effect on other colony members. Behavioral observations and weight measurements were conducted on a complete captive colony, and two litters (n=5 and n=3) were examined. The results showed discrepancies in growth rates within a litter, as well as in the amount of "work" performed. Based on the results it may be concluded that a predestination of castes does occur. Also, there exists a certain chronology of different types of work (digging, tunnel maintenance, food hoarding, nest building etc.) in which the animals are involved over time. The newborns were fostered by both the infrequent and frequent workers, however the infrequent workers exhibited a greater overall body mass change throughout the study.

Key words: Bathyergidae, eusociality, caste, frequent worker

Introduction

The Damaraland mole-rats (*Cryptomys damarensis*, Ogilby W.1838) are, together with the naked mole-rats (*Heterocephalus glaber*, Rüppell E. 1842), the only truly eusocial mammals discovered thus far (1). Bennet and Faulkes define eusociality as "reproductive division of labour, overlap of generations and cooperative care of the young" (Bennet & Faulkes 2000). Until the 1970s eusociality was attributed solely to insect species (Bennet & Faulkes 2000).

Damaraland mole-rats inhabit southern Africa, ranging throughout Zimbabwe to Namibia, and from southern Zambia through Botswana up to the Republic of South Africa. They live in social groups of 12 animals on average; the largest reported colony reaching 41 individuals (Bennet & Faulkes 2000). A single colony consists of a breeding female, 1-2 breeding males, frequent workers and infrequent workers (Bennett & Jarvis 2004). The colony is closely related genetically, and all its members foster the pups.

Although the related naked mole-rats have been studied extensively, little data is available on Damaraland mole-rats.

The purpose of this study is to investigate the recruitment of young into the working caste, as well as its influence on other colony members. The social role, or caste, of an individual is often related to its size, with the frequent workers being the smaller animals (Bennett & Jarvis 1998b). Since there is an influx of potential frequent workers with each new litter, it is hypothesized that as a consequence some of the older frequent workers might be "promoted" to the status of infrequent worker (as in Bennet and Jarvis, 1998) – or the litter may affect the colony members in another way. Furthermore, this study aims to observe the following:

1. When do the pups start actively contributing to the well-being of the colony?
2. Is the social role of an animal predestined, or does it change with age? Does it coincide with the animal's growth rate?
3. Do growth rates vary between the young? Is it related to their function in the society?
4. Does the new litter affect the castes, and/or weight of other colony members?

Materials and methods

Animals

The animals used in this investigation were a colony of *C. damarensis*, housed in the Natural Encounters building at the Houston Zoo Inc. in Texas, USA. The colony inhabited a tunnel system with eight chambers, two made of transparent plastic, and six lined with hydrostone. The hydrostone chambers were visible to the public, whereas the two others were located off-display. The animals used two compartments as bedrooms (one on- and one off-display), and one for food storage, where they hoarded food placed in various parts of the tunnel system. Sand, hay and cornhusks were used as bedding material.

The study commenced with a group of 25 mole-rats, nine of which were female, and fourteen male; the sex of two could not be determined. To facilitate proper identification, all of the animals were photographed prior to the study, and were later distinguished on the basis of the individual head markings.

The colony has been successfully reproducing throughout the past two years. Two litters of pups were examined, one born in June 2005, eight weeks prior to, and the other halfway through the study (October 2005), which granted an equal amount of observations for the comparison of the colony's behavior before and after the birth of a litter.

Behavioral observations

The investigation was conducted over a period of 14 weeks, from Sep 9 until Dec 17, 2005. The colony behavior was assessed based on regular observations of approximately 6 hours per week, during which time the behavior of each animal was noted, following the methodology of Bennet and Jarvis (Bennett & Jarvis 1998b). The types of work focused on were maintaining the tunnel system (sweeping debris with energetic kicks of the hind legs), digging, hoarding food, and nest building, i.e. hoarding and arranging nesting material. Other noteworthy behaviors as well as the development of the newborns were also recorded.

In order to enable a better investigation of the social roles of individual mole-rats, the observations were often conducted during the feeding times.

Weight measurements

Each animal was weighed eight times throughout the study, at intervals of one to three weeks. The June litter was weighed one additional time. The measurements were taken in the morning, before the regular feeding time.

Software

The software employed in data analysis was SPSS 14.0 and Microsoft Excel.

Ethical note

This investigation was largely observational and non-invasive and did not involve exposing the Zoo Animal Collection to additional stress. The interference with the animals' normal daily regimen was reduced to an absolute minimum. The project was approved by the Houston Zoo Inc. Institutional Investigative Studies Committee.

Results and discussion

Development of young from the June 2005 litter

The older litter consisted of five animals born on Jun 29, 2005, who were still juveniles at the beginning of the study. The activities of these animals were observed along with those of the other colony members, but analyzed separately (see Table 1, Figure 2). Apart from the activities described in Fig. 2, juvenile mole-rats engaged in playful teeth-fencing and chasing, mainly among themselves, but also with older animals.

The weight measurements (Fig. 1) show certain discrepancies between the individuals. While three juveniles (22, 24 and 25) were rather uniform in their body mass, two others showed a departure from the average. The growth rate of one animal (no. 23) was much higher than that of the other mole-rats (m=0.5). At the same time, although animal no. 21 appeared to be much smaller than its siblings, it still maintained a growth rate close to the average one (m=0.4). Consequently, the disparities between no. 23 and the other animals escalated with time.

The weights of the animals correlated negatively with the percentage activity exhibited after the birth of the October litter (Table 1). The largest of

Table 1. Percentage of "work" engaged in by the young from the June 2005 litter before and after the birth of the October 2005 litter

Animal no.	% work before	% work after
21	21.4	25.7
22	35.7	17.1
23	19.0	14.3
24	9.5	20.0
25	14.3	22.9
TOTAL	100.0	100.0

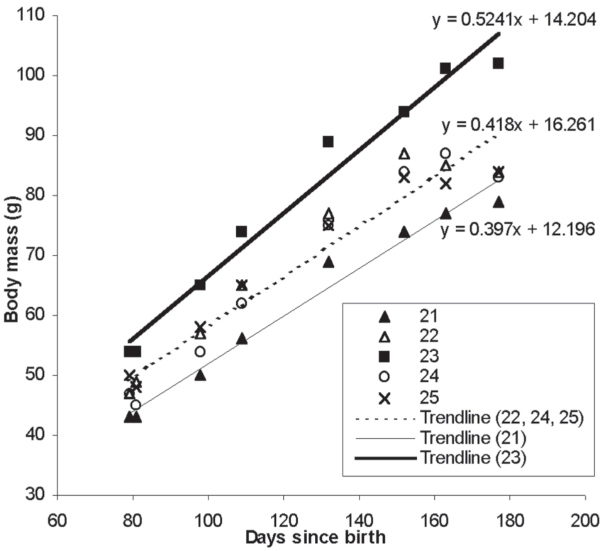

Fig. 1. Growth rates of young from the June litter (animals 21-25). The trendlines for animals 22, 24 and 25 were averaged and displayed as a single line due to their close values

the litter, no. 23, engaged in the lowest percentage of work (14.3%), and the smallest one, no. 21, in the highest (25.7%). This is not as obvious throughout the first half of the study, where a correlation between the body mass and the percentage activity cannot be clearly defined.

Furthermore, there was a change in the percentage engagement in certain types of activities over the course of study. In particular, a great increase in sweeping was noticed (2.4% to 34.3%), as well as a decrease in digging and food hoarding.

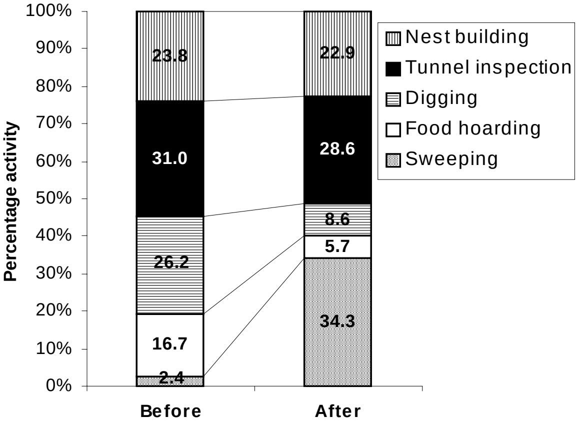

Figure 2. Different categories of "work" (percentage of total) engaged in by the young from the June 2005 litter before and after the birth of the October litter. The periods covered are Sep 9 to Oct 22, and Oct 23 to Dec 14, 2005

Postnatal development of the October litter

On Oct 23, 2005, the breeding female gave birth to five young. Two were covered in short, velvety, dark gray hair, and were larger than the remaining three hairless and weak ones. All pups were born with incisors (about 1-2 mm long), and could crawl within the first day of birth. Their hair and skin coloration clearly showed the adult white head markings. The colony displayed very limited care of the young, leaving them alone in the food storage chamber for hours, and taking no notice of them. The pups were trampled and kicked by the older animals, in the same way as debris was kicked during tunnel maintenance. A few of the older animals were occasionally taking care of the young, i.e. grooming or carrying. One of the less precocious offspring died two days after birth, another one two days later. The surviving babies were referred to as 31, 32 (precocious) and 35 (the remaining weaker one). There was a great discrepancy in development of the three pups as far as body mass was concerned, as well as fur growth and dexterity. Animals no. 31 and 32 were able to walk short distances (about 20 cm) on their own one day after birth, and started grooming themselves within a week. Their coordination progressed until the age of 24 days, when they could walk steadily, while no. 35 was still being carried by older mole-rats for another week.

The young were first observed hoarding food 42 days after birth; the trips were short, covering a distance of about 30 cm. They first started using their teeth to dig at the age of 50 days.

Other colony members

Based on their initial body mass and the type and amount of "work" performed, as well as observations of the zoo staff, the animals were assigned castes following the same criteria as those described by Bennet and Jarvis (3). These calculations excluded the breeding female, young from the last two litters, and a young male who died eight weeks after the commencement of the study (necropsy did not reveal the cause of death). The remaining animals were classified into eight frequent and nine infrequent workers. Since the copulation occurred outside of the observation period, it was impossible to determine the breeding male.

The mean weight of each animal before and after the birth of young was compared. Although some differences reach as much as 15.25g, they did not correspond to behavioral changes. Nevertheless, the Mann-Whitney test showed that weight differentiation is significantly higher among infrequent workers ($n=18$, $p<0.10$).

Discussion

Both the observations of the October litter and the percentage analysis of the work performed by the June litter suggest that there exists a certain chronology of tasks in which the animals are involved over time. Youngest animals are recruited into the working caste at the age of about 6 weeks, their first tasks being hoarding food and nesting materials. Later they begin to engage in digging, and finally in sweeping of the tunnel systems. Although they continue all of the activities, the percentage of time devoted to them changes with age; this could also be related to the size of the animal.

Basing the conclusions solely on the June litter, it can be inferred that a predestination of castes within the colony does exist. The fact that one of the animals exhibited a higher growth rate and a lower percentage engagement in the work activities supports the thesis that an individual is born into a caste. However, it is uncertain whether the caste itself is an effect of the size (i.e. a juvenile becomes an infrequent worker because it is bigger at birth), or its cause (a juvenile grows faster because it is an infrequent worker). This should be reexamined with a greater number of litters. Bennet and Jarvis (4) suggest that playful sparring between the pups contributed to the determination of the caste, which could also be taken into consideration in further studies.

Contrary to the results obtained by Bennet and Jarvis (4), the animal spending the greatest amount of time attending the newborns was an infrequent worker. Although there was no worker "promoted" to the non-working caste, as expected in the hypothesis, the results of the Mann-Whitney test show that the new litter's birth and recruitment seemed to have a greater effect on the weight of infrequent workers than frequent workers.

Although this project provides a number of interesting behavioral observations, it should be repeated with a greater sample to increase the credibility of the quantitative analyses.

Due to the fact that the chamber system was located in two rooms, it was sometimes difficult to observe the entire colony at once, especially during periods of intensive activity in both parts of the enclosures.

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Can vervet monkeys learn new behaviours in a social context?

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Abstract: Researchers argue that social learning, as one mechanism of transmission, is directly relevant to our concerns about social intelligence. The aim of this study was to examine the behaviour of *Cercopithecus aethiops* in order to establish which is the social learning strategy adopted by these monkeys to acquire new behaviours. 9 vervet monkeys hosted at Parco Natura Viva – Garda Zoological Park and 5 housed at Parco Cappeller, in Italy, were presented with five different boxes to open in order to retrieve a reward. 9 monkeys of Parco Natura Viva saw a human demonstrator opened each box several times over two different sessions whereas the remaining five vervet monkeys, employed as a control group, did not. The results of this study show that the performance of vervet monkeys was better when they observed a demonstration than when they did not. However they did not reproduce the sequence of the behaviours observed. Thus, our findings suggest that vervet monkeys can learn new behaviours by observing others. Local and stimulus enhancement have certainly played a role in learning new behaviours even if emulation may be the strategy adopted by these monkeys to acquire new behaviours. However, it seems that there is not imitation.

Key words: Vervet monkeys, social learning, new behaviour

Introduction

In recent years, many studies on how new behaviors are learned by observing others, have resulted in a radical reappraisal of the concept of imitation. Whiten and Ham (1992) for instance call *stimulus enhancement* when individuals learn from the model "to what object or location to orient behaviour". Tomasello (1990) names *emulation* the learning from a model about the various properties of an object, its relationship to other objects and its final state after manipulation. The term "imitation" is reserved to action copying which is guided by attribution of a goal or intention to the model (Tomasello, 1990; Bekkering, Wohlschlager & Prinz, 2000). The latter concept of imitation is distinguished from mimicry in which movements are copied without an understanding of the model's goal. The importance of the role of imitation is well expressed by Meltzoff's words suggesting that the name *Homo sapiens* should be replaced with *Homo imitans*. To better understand the role played by imitation in learning the use of tools, we carried out a study on social learning. Over the past decade there had been increasing multidisciplinary interest in the topic of social learning (*e.g.*, Box & Gibson 1999; Fragaszy & Perry, 2003; Heyes & Galef, 1996). Some have focussed upon the underlying cognitive mechanisms (e.g., Heyes 1994; Laland & Bateson 2001), others have considered its role in non-genetic inheritance and the resultant adaptive significance of it (e.g., Lefebvre & Giraldeau 1996). The topic of Social learning is also central to the debate as to whether non-human animals can be said to possess „culture" (e.g., Tomasello, Kruger & Ratner 1993). In this paper, we investigate the social learning of vervet monkey (*Cercopithecus aethiops*) focussing primarily on the issue of mechanisms.

Aim of the study

The present study intended to bring up the strategy adopted by *Clorocebus eathiops* in acquiring new behaviors to solve tasks through observation.

We aimed at verifying:

1. whether seeing the model improves problem solving performance of individuals as compared with mere exposition to the apparatus,
2. whether vervet monkey can use information gained by observation in similar situation,
3. whether they can replicate an entire sequence of the observed actions.

Thus, can vervet monkey imitate? If not, which is the social learning strategy adopted by these monkeys?

Material and methods

Subjects

The subjects of this study are 14 vervet monkeys hosted in two different zoos:

- 9 vervet monkeys hosted at Parco Natura Viva – Garda Zoological Park plaid as *experimental group*,
- 5 vervet monkeys housed at Parco Cappeller were employed as *control group*.

All subjects were presented with five different boxes (Fig. 1) to open in order to retrieve a reward.

P rocedure

Subjects were asked to perform five problem solving tasks.

Control Group (5 subjects):

- subjects were habituated to the experimenter's presence and to take reward from a wooden box;
- subjects were exposed to the apparatus and left alone to solve the problem.

Experimental Group (9 subjects):

- subjects were habituated to the experimenter's presence and to take reward from a wooden box;

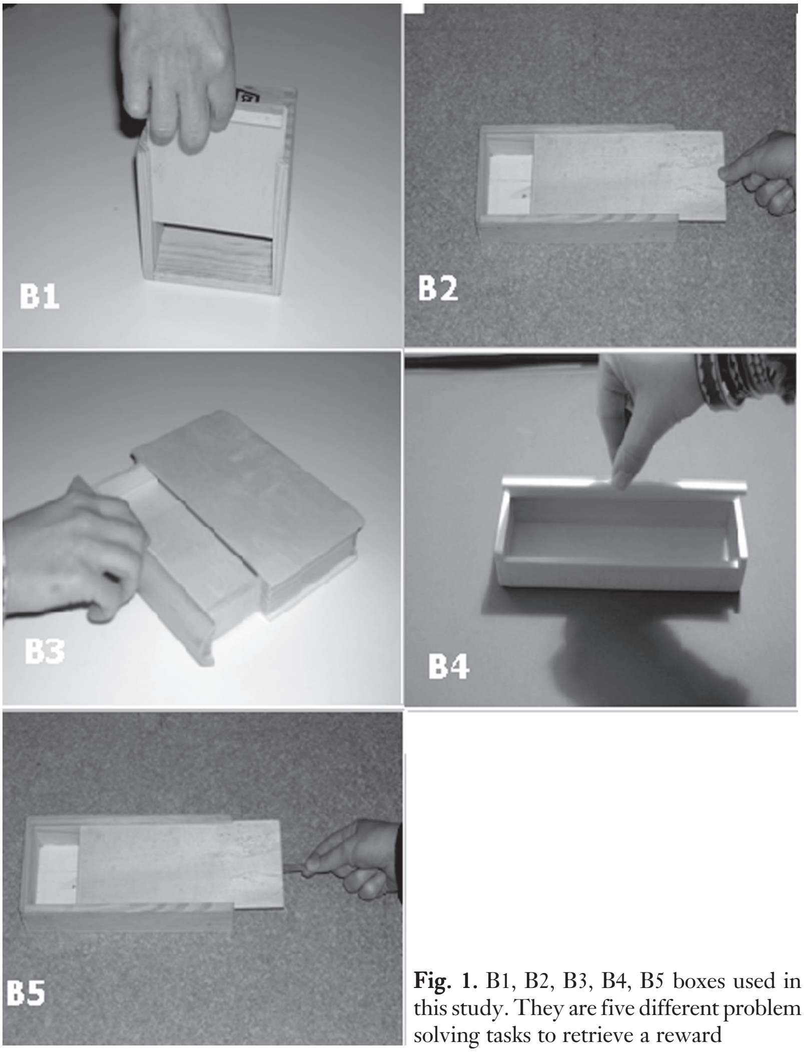

Fig. 1. B1, B2, B3, B4, B5 boxes used in this study. They are five different problem solving tasks to retrieve a reward

- subjects were asked to perform the tasks after having seen the correct solution shown by the model (Demonstration).

Demonstrative sessions (Experimental Group only): a human model demonstrated how the apparatus could be opened. There were 2 Demonstrative sessions x box x week. In each session 20 demonstrations were performed from the inside area and 20 demonstrations from the outside area (a reward was given to the subjects after each demonstration form the outside area).

Manipulative sessions (Experimental Group and Control Group): the subject could manipulate the boxes in order to open them to retrieve a reward. The Experimental Group was employed with two 2 Manipulative sessions x Box, whereas the Control Group had 1 Session x Box.

All sessions were videotaped with a Sony Handcam mini DV.

Results

Observation

To evaluate whether subjects looked during the demonstrations, we calculated the percentage of visual orientation toward the demonstrations and the percentage of critical moments observed. The results show there is a great variability of observation across subjects (mean 12%). However there is a significant correlation between the percentage of observation during the Demonstration session and the percentage of attention at the Critical Moment (*Spearman Correlation*: *Rho* = .952; *p* = .012, Fig. 2).

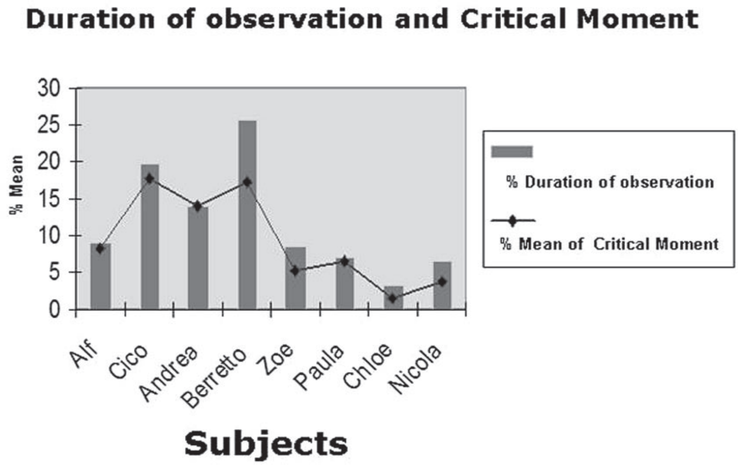

Fig. 2. The mean percentage (+ SD) of duration of observation and frequency of Critical Moment

The percentage of observation was significantly higher toward demonstrations in the outside area than in inside one. This could be due to the fact the subjects received reward only when they observed the demonstration in the outside area. Thus, the reward could motivate the subjects to look toward the demonstration. Indeed, the subjects looked more during the demonstration of the outside area (where the reward was given) than of the inside area (without reward). The percentage of observation toward the Demonstration sessions in the outside area was similar across boxes, whereas differences of percentage of observation were found across boxes during Demonstration session in the inside area. Especially, during demonstrations of the first session differences, were found significant (*Friedman Test*: *X2* = 11.522; *p* = .021; Fig. 3).

Manipulation

All the monkeys of the experimental group manipulate the boxes at least once. No significant differences were found for the performance of the subjects shown for the very First Touch Action across boxes in the two sessions (*Friedman Test*: N.S.; *p* > .05; Fig. 4). Furthermore, not significant differences were found for the First Touch for each box between the two Manipulative Sessions (*Wilcoxon Test*: N.S.; *p* > .05 x each box; Fig. 4).

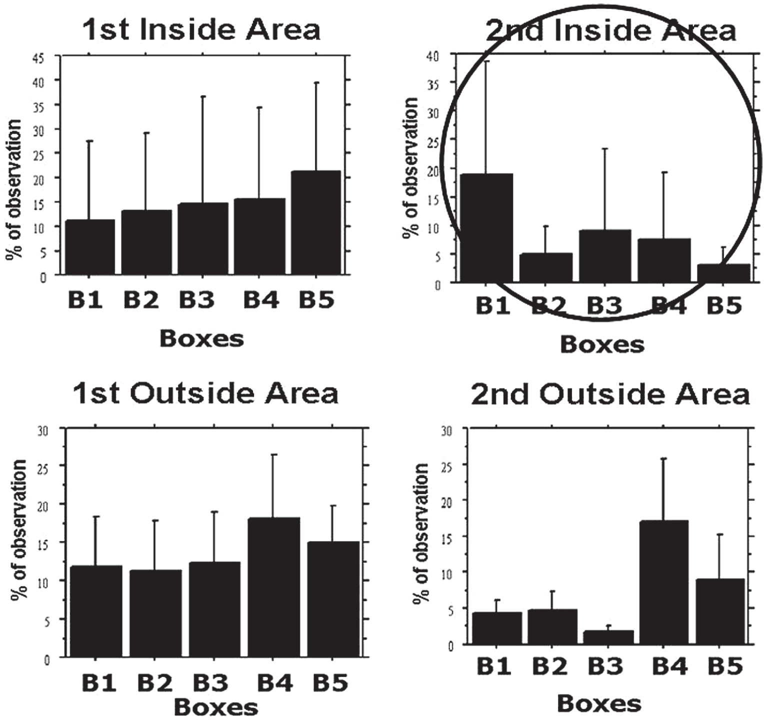

Fig. 3. The mean percentage (+ SD) of duration of observation

All the subjects of the experimental group, apart from Cico, who was the dominant male, were able to open at least one apparatus to retrieve the reward. Since there were not significant differences between the two manipulative sessions in the perfomance of the vervet monkeys to open the same box, the new behaviour could be acquired and begun part of the repertoire of the individuals (*Wilcoxon Test*: N.S.; *p* > .05 x each box; Fig 5).

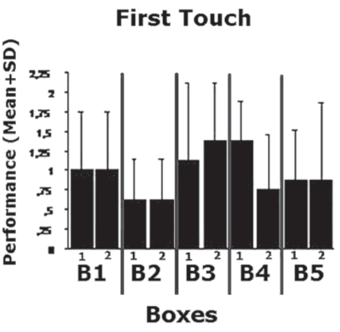

Fig. 4. First Touch. The mean performance (+ SD) of the experimental group during manipulation: the very First Touch Action

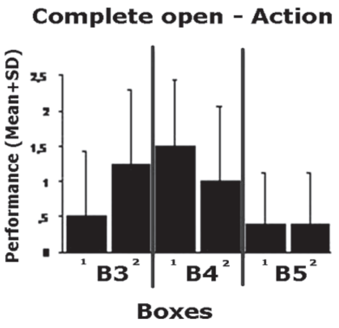

Fig. 5. The mean performance (+ SD) of the experimental group during manipulation: the First Touch of the Complete Open Action

Observation & Manipulation

During the first interactions with each apparatus the perfomance of the subjects of the Experimental Group were significantly better than the performance of the Control Group ones (Mann Whitney Test: B1: $U = 5.000; p = .0151$, B2: $U = 7.500; p = .0304$, B3: $U = 7.500; p = .0336$, B4: $U = 0.000; p = .00018$, B5: $U = 5.000; p = .0136$).

This result suggests that vervet monkeys can gain information form the observation of the demonstration on how to solve an apparatus to retrieve a reward. Indeed the subjects of the Control Group that were not shown any demonstration were unable to open the boxes, and furthermore did not even manipulate them. However, the correlation between the percentage of observation during the Demonstrative sessions (Duration and Critical Moment) and the performance shown by subjects during the Manipulative sessions was found non significant (*Spearman Correlation*: N.S.; $p > .05$). This could be due to the fact that a long and repetitive exposition to demonstration is not necessary to learn how to solve the task.

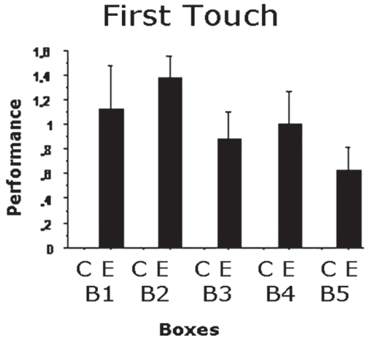

Fig. 6. The mean performance (+ SD) of the experimental group (E) and the control group (C) during manipulation: the very First Touch Action

Conclusions

The results of this study show that the performance of vervet monkeys was better when they observed a demonstration than when they did not. However, it seems that a few number of demonstration/exposition is sufficient for individuals that leave in social context to learn new behaviours from others. Thus, even if they did not reproduce the sequence of the behaviours observed, our findings suggest that *Cercopithecus aethiops* can learn new behaviours by others and local and stimulus enhancement have certainly played a role in learning new behaviours. However, emulation may be the strategy adopted by these monkeys to acquire new behaviours.

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Breeding of sugar gliders (*Petaurus breviceps*, Waterhouse 1839) captive population in Moscow zoo

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Abstract: The research on sugar gliders (*Petaurus breviceps)* breeding and social behavior took place in Moscow Zoo, Scientific Department, in the period from December, 2004 to January, 2006. We studied two pairs and five family groups, which included adult, subadult and juvenile animals. For registration we used videotaping and such methods as time sampling and continuous journaling. All together 476 hours of observations had been processed. In the period when adult male and female are introduced to each other, the establishment of friendly relations takes place and only afterwards mating occurs. Great variety in behavioral repertoire and evident superiority of friendly contacts shows that this species appears to be highly social. Apart from the process of pair formation, we described the state of females pouch depending on their reproductive status, and stages of development of the young. In all family groups, each animal has its own role, which depends on individual characteristics of this glider. It is typical for sugar gliders juvenile to have relatively long "childhood", when social learning occurs. In raising a juvenile mother undoubtedly plays the main role, but all other members take part as well.

Key words: sugar glider *Petaurus breviceps*, parental behavior, pair formation**,** captive breeding

Introduction

Sugar gliders inhabit open forests in eastern Australia, New Guinea and Tasmania. These smart and attractive animals are social, in the wild they form family groups containing up to 7 adult animals and their young (Nowak, 1991). Nowadays sugar gliders are common in zoo collections and many people keep them as pets. Nevertheless many aspects of their biology, particularly reproduction, are not studied well, in many respects because of their nocturnal activity and secretiveness. And so there are hardly few publications devoted to pair formation and maternal behavior of sugar gliders.

This species has being kept in Scientific Department of Moscow zoo scince 2000. The main goal of the present study was to characterise captive breeding of sugar gliders. For that we:

1. Analysed all breedings of sugar gliders' colony in Moscow zoo in 2004-2006;
2. Video-taped the process of pair formation;
3. Described mother-cub interactions in five family groups;
4. Estimated effect of all group members on development of the young;
5. Described onthogenesis of the young and dynamics of their behavior from the moment of leaving the pouch up to the end of weaning period.

Material and methods

We collected data in Moscow zoo during 2004-2006. Animals were housed at 26°C in vertical cages (80x40x130 cm) in the room with reverse schedule of light. All cages contained tree branches for climbing, two wooden nest-boxes, feeding and drinking bowls. The nest-boxes each had one glass side to make animals visible permanently. Out of observations we closed that glass sides with cardboard pieces. Animals were fed on a daily routine; their diet consisted of fruit, insects, cottage-cheese, boiled eggs, honey. All our sugar gliders were marked individually by cutting off hair on different parts of body.

Before starting the main observations, we video-taped behavior of sugar gliders in two family groups (24 hours of taping for each group). This helped us to reveal peaks of animals' activity and to compile ethogramm of this species. Our following observations were conducted 2-3 times a week under red light, lasted about 3 hours and were timed to the period of top activity of animals. Pouches of nonpregnant females were examined once a week.

To study pair formation in two pairs of sugar gliders 144 hours of video-taping have been done and analysed.

During observations on interactions between juvenile and adult animals (284 hours) we fixed all contacts, appearance and forming of new behavioral acts and duration of stay of the young out of nest-boxes. Five family groups were under the study. They consisted of 6 males and 7 females who produced 8 litters (10 young) during the analysed period.

So, total time of observations was 476 hours. Also we kept a diary of all events in parallel. While analysing breeding of the species in Moscow zoo, we used data on 14 litters (18 young, 4 of them have died).

Results and discussion

Differences in behavior of our captive sugar gliders are significant and concern individual behavior as well as social on all stages of pair formation and further breeding. That's why our subsequent discussions are generalized.

Pair formation

To form a reproductive pair we commonly united the partners in a neutral territory. For several days, female was kept alone in the new cage. Then we introduced a male.

On the whole they showed mutual interest by a lot of sniffing (up to 68% of all the contacts). Few agonistic interactions initiated by the female have been noticed, but they didn't cause any damage to the male. Considering two pairs introductions the whole period of pair formation could be divided into several stages:

1. On the first day of introduction, apart from high social activity, the animals showed exploratory activity and marking.
2. During the second day the animals started coming closer – they spent more time together, different types of sniffing prevailed; at the end of the active period the sugar gliders sheltered in one and the same nest-box to sleep.
3. The day before mating the female showed some sexual activity, such as mounting the partner, clenching his neck, as well as social grooming.
4. Sexual behavior included anogenital grooming, male mounting and female mating game. The female involving the male stood in front of him and her tail started to wriggle. Then she turned her back to the male still keeping the tail wriggling and touching the male's nose. Such behavior provoked the attempts of male mounting. The mating took place in the nest-box, where the partners spent 7 hours. Continuous grooming preceded the mating, two copulations followed, which precise duration we couldn't estimate. After mating the female went into another nest-box, and stayed there for a long time. Male followed her around and spent his time sitting on the roof of that shelter.
5. The day after mating male was initiative for most of the contacts (up to 60%).
6. The animal relations grew stable during the following days: state of partners' activity and the number of social contacts didn't really vary. So, we concluded pair formation period to be finished.

To sum it up, the mating took place with both observed pairs of sugar gliders during the first 6 days of introduction. Firm social bonds have been formed between the partners. In both cases introduction successfully led to reproduction. Nevertheless, the length of pair formation period between different sugar gliders may vary.

Pregnancy

According to the literary data the sugar gliders' pregnancy is about 16 days, which coincided with our own observations. No postnatal estrus is observed. It's impossible to identify pregnancy if to rely on the female weight dynamics, because the young weigh 0,19g at birth (Nowak, 1991). From our experience, the beginning of pregnancy can be diagnosed by the state of the female's pouch (Jackson, 2003). A female, which hasn't given birth before, has a small, clean and dry pouch without skinfolds, the teats being very small, as well. A female that have bred previously but not presently, has a small but distinct, dry and dirty pouch, the teats are slightly elongated. Pregnant females pouch is pink in colour and glandular in appearance, skin folds may be observed on the lateral margins.

Baby in the pouch

After birth cubs migrate to the pouch by themselves. They attach to the teat and don't get off for approximately 40 days. They are always located upside down in the pouch.

The birth usually stimulates the female to build a nest. With the tail curled into a loop, the animal heads for the chosen object (a stick, hay or a leaf), picks it up with its fore feet and hangs upside down clinging with its hind feet. Then it puts the material into the loop on the tail and starts its slow way back. Though, sometimes they fail to make it all the way to the nest-box. They also carry sticks in their teeth. Such a nest building behavior is peculiar not only for females but sometimes for males.

According to our observations, while having a cub in the pouch, females groom mostly in the nest-box. They roll over in order to lie on the back: this way the lower part of the body leaning upon the wall and turns out to be higher than the head. After that the female stretches the pouch with its forepaws and licks it over.

Cub makes its way out of the pouch

Cubs start leaving the mother's pouch at the age of 70-74 days. At this time they are ill-developed with poor thermoregulation. At first, the cubs are blind and almost bare. The body gets hair starting from the back and ending up on the belly. The ears go up gradually, the eyes fully open 6-10 days after leaving the pouch. The lower incisors are rather well developed, the upper ones show up in 25 days. From the first day after emerging the pouch they can produce barking sounds – the scream of the left alone cub. Quickly enough they make their acoustic repertoir wider.

The process of leaving the pouch takes place also gradually. During 2-3 days the cubs leave the pouch for a short period of time and come back. At this time they can perfectly cling to mother's fir. Little by little they spend more time outside and climb on mother's back. They easily find the way back to the pouch, the muscles of which are always relaxed at this period. The skinfolds are not distinct, the pouch hair is rare and dirty, the skin is smooth and dark pink, the teats are very elongated.

Female spends a lot of time in the nest-box, so the cubs gradually get off her. In cases when the female leaves the nest and the cubs are left all alone, they doubtingly move about the nest-box, sometimes sit helpless shivering, dropping the head from time to time. Approximately 10 days after they leave the pouch, when the eyes are wide open, the cubs can sit without falling and start moving around more. We observed the case, when the female was dragging a stick into the nest to make it easier for the cubs to climb. At the same time the female starts bringing food for the cubs. One of our females used to bite the head of an insect off, push and pass it to the cubs. They would lick the content but didn't try to hold it in their paws at that age.

In the course of two weeks after leaving the pouch, the cubs get out of the nest only on top of the mother, sometimes on the male, but later they do it by themselves. Gradually they investigate the cage area and learn to jump. The first planned jump was noticed 21 days after leaving the pouch. During the walking-out the adult gliders follow the cubs.

The cubs start playing two weeks after they leave the pouch. First of all they play individual games with their tails and nest material. Few days later the cubs play with each other or with adult animals. Games include catching the partner by the fore feet, pouncing, crawling under the partner and running one after another. Later the adult gliders get involved in similar games. We noticed some elements of sexual behavior (neck bites, mounting attempts, tailset bites) in juvenile games.

During the weaning period and when cubs were leaving the nest, females used to become aggressive toward the keeper (seldom to other members of the group). Female aggression disappeared after the end of lactation period.

Also, a very strong outdoor activity decrease has been noticed among the females after the young left the pouch. During the first days, female spends a lot of time with the cubs in the nest, though feeding happens not oftener than once an hour and a half, or two hours. Cubs' thermoregulation is ill-developed at this stage, that's why female can't leave them alone in the nest-box for a long time. Later female visits the nest-box more seldom and stays there only for feeding and grooming the cubs.

Usually mating takes place at the end of lactation period, so the reproduction happens once in 6 months. Supposedly, cubs leaving the pouch contribute to a female hormonal balance change. Indirectly it's proved by the male behavior at that moment: elements of sexual behavior have been noticed (anogenital area grooming, following the female, attempts of mounting). One of our females produced three litters during our period of investigation, and twice the mating happened almost right after the previous cub had left the pouch. In both cases the interval between reproduction became twice shorter, but all the litters developed normally. Such a phenomenon is common for other marsupials, though it has never been registered among the sugar gliders (Dr. David Croft, personal comment).

The end of weaning period

All the young had approximately the same dates of development. 40-45 days after the pouch leave they all became independent. By that age they had successfully finished investigation of the whole cage area, and could move around independently from the parents. Sometimes, though, they kept riding on female back. They would independently go down to the feeding place, eat and drink water. We could observe a well-formed grooming complex before and after sleep. The weaning period stopped when the cubs came to an age of 110-120 days.

Helping behavior

The presence of grown up cubs doesn't prevent the main pair from breeding. Short after the end of lactation period, female cycle usually restores, mating takes place, and new litter appears. Immature group members show increased interest towards newborns when the latter leave the pouch. They play with them and carry them on top. Optionally paternal behavior comes out – some males build a nest, carry cubs on top, and are respondent to their signals. We observed two cases when mother's attention was distributed among the cubs not equally: she gave distinct preference to one of her daughters. That cub spent most of the time on top of mother. Sometimes mother would deliberately drop the other cub down in order to leave it in the nest. In that case father would partially compensate the lack of mother's attention: he began to spend more time in the nest-box together with the left alone cub. And when the cub started going out of the nest independently, it followed the father, not mother, imitating him. Often the father would sleep in one nest-box with that cub, separately from other members of the group.

Sexual maturity

According to literary data, sugar gliders become sexually mature by the age of 12 months (females), and 8-15 months (males) (Nowak, 1991; Jackson, 2003). Males from our colony started breeding approximately at the mentioned age but females recorded as mating were aged 11 months.

Sexual maturity of males can be judged upon development of their frontal gland. There are three stages of its activity (Jackson, 2003):

1. Little or no activity – little or no hair loss over the gland area; no obvious gland product.
2. Medium level activity - some loss of hair over the gland area; waxy glandular products visible.
3. High activity – total loss of hair over gland area; waxy gladular product prominent.

Female sexual maturity and the beginning of reproduction can be determined according to the changes of the pouch, as it has been described above. When young females start to breed, they can stay in the group or may be driven away, this depends on behavior of adult female. Young males start their breeding in the group if the group includes not only adult but young females, too. Then the young male and the young female form a new pair and occupy the free nest-box. We used to separate such a pair.

General data on reproduction

Having analyzed all the cases of sugar gliders' reproduction in Moscow Zoo for the period of September, 2004 – April, 2006, we got the following data.

All formed pairs (n=9) initiated reproduction. 14 litters appeared during the mentioned period, with 18 cubs in total. Among them were 11 males and 6 females; one cub couldn't be sexed. No seasonal differences in reproduction have been noticed; the litters appeared evenly during the whole year. Most females reproduced only once a year, but there were cases when the female produced two (n=1), and also three litters (n=2) during 12 months. Young females, just starting to breed, produced one litter during the year, and only one female reproduced twice. In 65% of cases there was one cub in the litter, and two cubs in the rest of cases. Out of 18 cubs 4 died: one, being in the pouch, the others – soon after leaving the pouch. In all those cases, they were the cubs of females, which gave birth for the first time. The cubs of such females survived in 55% of cases.

Conclusions

To sum up, sugar gliders are social species with strong family relations. The behavior of all the animals depends on each other. The birth of a cub and its leaving the pouch plays a very important role for the whole group. A newborn is fully dependable on mother's attention and on other members of the group. Gradually developing, it gets to know more about the outer world, learns actively, and approximately in 45 days after leaving the pouch, becomes independent.

The process of sugar gliders pair formation, the phenomenon of shortened interval between reproductions and some peculiarities of parental behavior have been described in the present work for the first time.

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The Polar Bear Female Behaviour before, during and after the Cubs' Birth

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Abstract: One of the most important events in the polar bear female life such as the cubs' birth was observed in the Leningrad Zoo. The female behaviour before the parturition, preparing to parturition, cubs' birth process and interactions between the female and her cubs during the first days were studied thanks to video recording.

Key words: polar bear, video recording, cubs' birth, Leningrad Zoo

Introduction

The Leningrad Zoo, which in 2005 was 140 years old, is one of the oldest in Russia. Polar bears have been kept at our Zoo for more than 100 years. Since the beginning of the 1930-s, for the first time in our country, these animals have reproduced regularly and during the last 60 years more than 100 cubs have been born here. It was the reason to make a polar bear the symbol of the Leningrad Zoo. At the moment there is one pair of polar bears at our Zoo.

Material and methods

By our recognizing, the polar bear female was to give birth at the end of November – beginning of December 2004. By that time two video cameras had been built in the polar bear female Uslada's cage. One of them together with an infrared lamp was fit into the den 's ceiling, the other one was focused on the cage where the den is placed. The information from the cameras came on a computer equipped with Geo Vision GV-600 (V6.03.0) programme. It is necessary to note that the recording on a disc was made from the camera installed in the den, the other one only gave the possibility to watch the female. That is why, while calculating time limits, the periods Uslada spent in the enclosure were not taken into account.

The video recording covers the period from November 26 (5 days before the parturition) till December 3, when the cubs became two days old. Regrettably, there are some gaps in the recording but the most significant periods including the twenty-four hours before the parturition, the twenty-four-hour period when the cubs were born, as well as the following twenty- four hours were recorded uninterruptedly. The recording, which includes 104 hours, was analyzed minute by minute.

The state of the lying female can be determined according to frequency and type of her breathing. When Uslada woke up, it became more frequent and less rhythmical. It should be mentioned that in some cases it was impossible to see what the female was doing as she was blocking the camera with her back. We regarded such activity as "stirring".

As the pictures were made from the video frames recorded with the camera built in the den's ceiling, they represent the view from above.

Results and discussion

The behaviour before the parturition

During the period from November 26 till November 28 we noted very low activity of the female. Mostly she was sleeping quietly, sometimes making some movements around the den, turned from side to side, changed the position of her limbs, stretched herself, licked the front paws, cleaned and did some other comfortable actions. Very seldom, not more than once a day, she left the den.

24 hours before the parturition Uslada was mostly lying awake, with her eyes open, but the number of comfortable actions increased, as well as the number of position-finding reactions such as raising the head, looking around and sniffing. During that day (November 30) the female took walks in the cage twice and they lasted about an hour (Fig. 1A). It was then when the den-organizing behaviour could be noticed for the first time. Coming back to the den, Uslada started to shovel the hay aside and scretch the floor in the centre of the den. It is necessary to say that though these actions took not longer than 5 minutes, we can suppose that such behaviour could have been shown before but it had not been recorded. This can be proved by the fact that when about a week before the parturition Uslada was given some pressed layers of hay, she used to take them away to the den and shovel.

During the twenty- four hours before the parturition the female often left the den for a long time and on returning began enthusiastically scratch the boards of the floor and of the wall opposite to the exit. Quite often the digging movements were directed towards the threshold and looked like throwing out snow from a den. Uslada was scretching mostly with her right paw, sometimes with the both ones in turn and also tore splinters off with her teeth. The time spent on organizing the den could be quite long – from 2 minutes to an hour and 10 minutes and the female could be scretching up to 40 minutes without any stop. Having a break, she used to sit down leaning against a wall and relax. Then Uslada started scretching again or went out into the cage. On the whole, during the twenty- four hour period before the parturition the den-organising behaviour took more than a half (55,6%) of the female's activity (Fig. 1B).

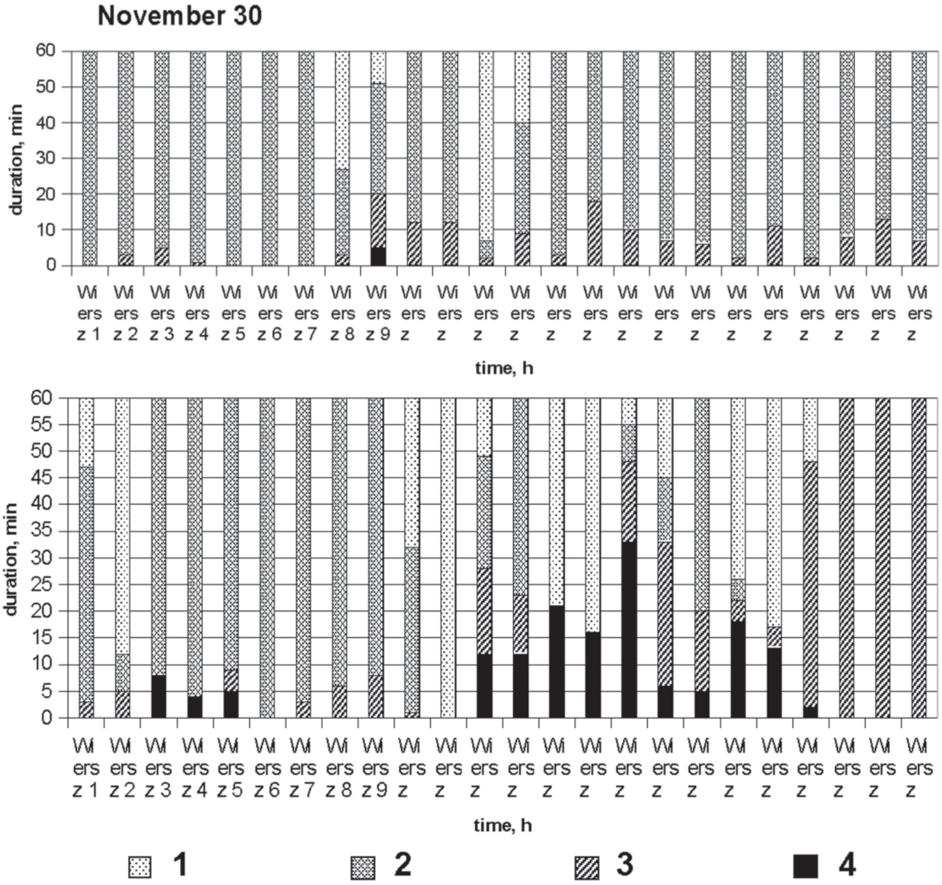

Fig. 1. Correlation between types of the female's activities during November, 30 (2 days before the parturition) and December, 1 (the day when two cubs were born)
Conventional signs: 1 – the time out of the den; 2 – sleeping and lying awake; 3 – all female actions except den-organizing behaviour; 4 – den-organizing behaviour; ▲ – parturition

The behaviour during the parturition

Two hours before the parturition the female began to show the signs of extreme anxiety. She walked round the cage looking into the den several times a minute but not entering it. At last, Uslada came in, began scretching the floor, turning, licking herself clean and at 8.21 p.m. on December 1 the first cub was born. The female turned to the newborn, sniffed it, lay on her stomach and, having placed the cub between her front paws, started breathing on it and licking it over.

Then, with the help of her snout and tongue, Uslada put the cub up to her shoulder, covered it with the front paw, hid the snout between the front paws and started warming it with her breath.

In an hour or so the female began to worry again, stood up, put the cub down, covered it with hay and went to another side of the den. The second parturition started in an hour and a half after the first one. It could be clearly seen as the female was standing bent, looking under her belly and then delivered a cub with her front paw. She licked it over, then took its head into the mouth, put into the corner where the first cub was lying and sat in front of them breathing hard. After that Uslada lay down in such a way that the cubs were beneath her neck, then moved them onto her shoulder, covered with the upper paw and started warming them with her breath. From time to time the female checked the cubs putting a one crawling out back, sniffed and licked them over but, on the whole, she made very few movements.

In two hours and a half after the second parturition (in four hours after the first parturition) the third ones began. The female was lying on a side keeping the two cubs between the front paws and breathing on them. Suddenly she began to worry and look around, put out the hind paw and two strong contractions went over her body. Holding the cubs back, the female moved aside from the place where she had laid and sniffed the newborn. She licked it over and joined to the first ones.

There was made an attempt to determine the size of the cubs. The length of the lying on the floor cub's body was calculated relatively to the width of the den floor board. The length of the first cub's body was 30 cm, of the third one – about 27 cm. We did not manage to measure the second one.

The cubs could not be identified individually.

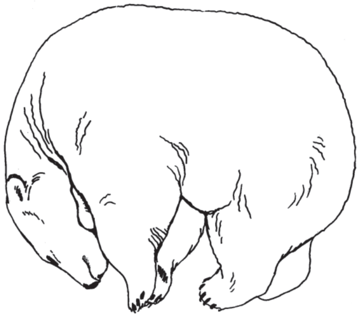

Fig. 2. Heating a cub between the neck and shoulder

Fig. 3. Heating 3 cubs between the forelegs. The moment when the female lifted her upper foreleg and the backs of the 3 cubs can be seen

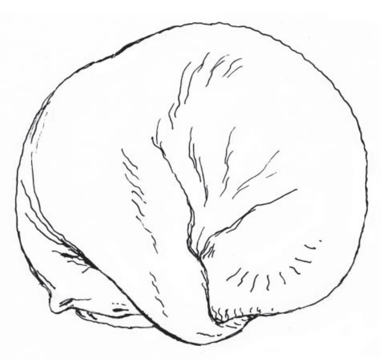

Fig. 4. The female curled in a tight circle

Heating of the Cubs

It is very interesting to watch how such a huge mother deals with so tiny children.

Uslada was constantly warming the cubs, only now and then putting them on the ground litter. As was said above, she placed the newborn cubs between her shoulder and neck (Fig. 2). Later she tried to put the babies on the inner side of the shoulder and the forearm of the lower paw and all the cubs could be held there at the same time (Fig. 3). From above the female covered them with her foreleg and, hiding her snout under it, warmed the cubs with her breath. Sometimes Uslada rolled up into a tight circle so that her adjoining lower hind and front paws made an unbroken bedding, while her upper ones – a vault above the cubs (Fig. 4). She could place one of the cubs between her neck and shoulder and the others – between her forelegs. During periods of rest, which lasted from 46 minutes to 2,5 hours, the female fell into drowsiness but as soon as the cubs crawled or fell out from under the paw she used to wake up and put them back. If Uslada did not react, the cubs became anxious and tried to get back under the paw. Their movements awakened the mother and she picked the cubs up.

Sometimes the female turned from side to side. To do so, she stood up, collected the cubs, clasped them to her bosom with a front paw or pressed them between her neck and shoulder, then turned and lay down again adjusting the babies with her snout and a paw. But more often Uslada left the cubs on the bedding, licked them over and took care of her own hair. The cubs stayed in the open air not longer than 10 minutes, but mostly about 3 minutes.

The major component of heating the cubs is the female's breathing. Its frequency, which can be clearly seen on the recording (a long deep breath and an abrupt exhalation), helps to determine easily Uslada's state. At the beginning of the observation, when the pregnant female was sleeping, the frequency of her breath was from 3 to 5 (usually 4) exhalations a minute, when she was staying awake it was 7-14 exhalations a minute. Since the very moment of the cubs' birth Uslada put them in front of her and warmed with her breath the frequency of which came up to 66-88 times a minute! The level stayed the same during the parturition of all the three cubs. The quickened breath (58-77 exhalations a minute) remained for about an hour after the third cub's birth. Gradually it became quieter and deeper and in an hour and a half after the third parturition the frequency lowered by half and in 3 hours it made 10-16 times a minute.

The cubs' feeding

Polar bear females have two pairs of nipples, which are situated quite close to each other. We will call the one closer to the neck the front or the first pair and the nipples become upper or lower depending on the side the female is lying on.

The first feeding could be observed in 6,5 hours after the third parturition. One of the cubs crawled up the female's lower paw to her body searching for a nipple and the mother was moving this paw putting it up to the needed place. More often a feeding from the lower nipple of the second pair could be observed during which a cub was lying along the female's lower front paw, covered from above with the other paw (Fig. 5). During a feeding from a lower nipple of the first pair a cub could be lying between the paws but more often it was between the female's shoulder and neck (Fig. 6). In this case it was less available for observation, which made impossible to define the frequency with which this or that lower nipple was used.

Fig. 5. Feeding of a cub from the lower nipple of the second pair. The moment when the female lifted her upper foreleg

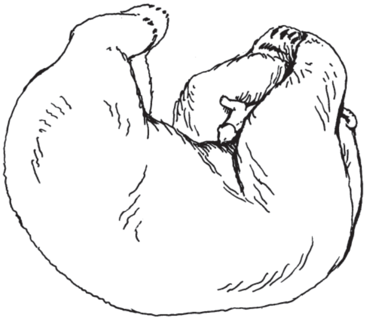

Fig. 6. Feeding of a cub from the upper nipple of the first pair. The moment when the female moved her upper foreleg aside

Fig. 7. Feeding of a cub from the upper nipple of the second pair

The cubs started using the upper nipples later than the lower ones, 18 hours after the third cub's birth, to be exact. The female lent back, slightly lifted her upper paw opening a nipple to a cub and then covered it with a paw or put it aside (Fig. 7). If a cub was sated from an upper nipple, it would crawl back to get warmed, whereas it could fall asleep on a lower one.

A "feeding" here means the whole process of a cub getting sated, even if it lost the contact with a nipple for some time but not longer than 15 minutes. We considered a feeding to be finished when a cub left a nipple and/or disappeared from the field of vision for more than 15 minutes.

Some feedings could not been wholly observed as the cubs were mostly hidden under the female's upper paw and could be seen only when she lifted or shifted it.

During the first twenty- four hours after the cubs' birth we observed 10 feedings which considerably differed in duration (from 8 min. to an hour and 18 min.) and type. Each of them has been analyzed.

The time of full satiety of a cub was 12-17 min. But many feedings lasted longer due to several reasons. Firstly, several cubs could be fed one by one. Secondly, having been filled, a cub could fall asleep on a nipple, thus making it difficult to determine when a feeding itself finished. Thirdly, two cubs could get to a nipple at the same time and, while competing, they started sucking in turn or the cub that got to the nipple later could push the one being on it. Finally, the lower nipples could turn out to be empty and in this case we could observe several short approaches when the cubs sucked for 1-3 min. and got back under the paw. It could happen when the female fell asleep and did not turn to the other side for a long time. When she changed the position, the cubs got sated and crawled away. There could be some other variations, as well as combinations of the abovementioned.

Sometimes it was possible to observe two cubs eating simultaneously (Fig. 8) but we could never see a feeding of three cubs at the same time. This fact makes possible to suppose that as a result of competition for the lower nipples, which are more comfortable, only two stronger cubs have the advantage. That is why litters of three cubs are quite seldom in wildlife.

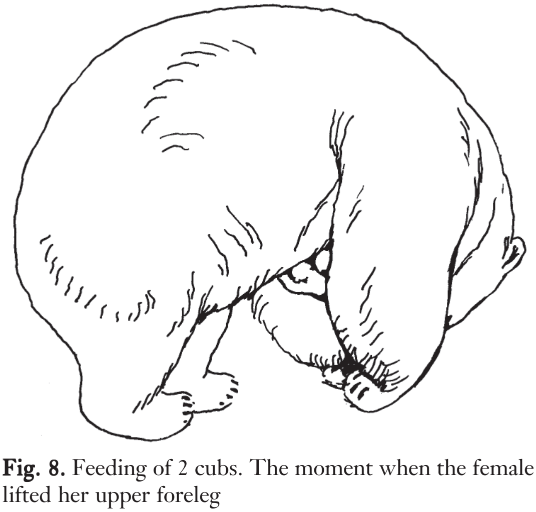

Fig. 8. Feeding of 2 cubs. The moment when the female lifted her upper foreleg

Conclusion

Thanks to the video recording we found out that three cubs were born but only one of them survived. Unfortunately, the reasons for the death of the other two were not found out as it had happened during a technical break when the recording had not been made. The cub that was born the first was bigger and more active than the third one (I did not see the second cub) and it had more chances to survive.

According to the abovementioned the following conclusions can be made:

1. Since the cubs' birth the female's behaviour was directed on minimizing their contacts with ground litter and staying in the open air.
2. The cubs were mostly warmed by the female's breath. Its frequency could reach 88 exhalations a minute, which proceeded the frequency of breath of a sleeping female.
3. Since the first hours there existed a competition between the cubs for being fed.

Acknowledgements. The author would like to thank the director of the Leningrad Zoo I. S. Skiba who has kindly afforded the opportunity to carry out the programme of video observation of the polar bears. I would also like to thank T. P. Petrova for illustrating this work and G. A. Afanasyeva, A. E. Ayrapetyants, M.V. Sokolovskaya and I.J. Maltseva for their invaluable help in collecting and analysing the material.

Some aspects of stereotypic behavior in an Asiatic elephant (*Elephas maximus*) female in a zoo

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Abstract: The daytime behavior of an Asiatic elephant female, kept in the Municipal Zoo of Wrocław, Poland, in an indoor pen and, weather permitting, an outdoor paddock, was scanned at constant intervals and the recording was continuous for 140 hours on 35 days for one year. The observation period was divided into five seven-day samples: spring indoors, spring outdoors, early fall outdoors, late fall indoors and winter indoors. Stereotypic sequences involved bouts of highly repetitive stereotypic movements proper and much more variable inter-bout behavior. Stereotypic movements were asymmetric and accompanied by protraction of the right hind leg and to-and-fro swinging of the trunk. The share of time devoted to stereotypic behavior was the lowest in the early fall when the elephant was regularly released to the paddock and the highest in the late fall after she had to stay in the pen after several months of spending days outside. This suggests that stereotypies are enhanced by changes of the management routine. However, on comparing the late fall and winter fixed management periods, stereotypies were much more frequent in the indoor pen than in the outdoor paddock, suggesting that the confinement to a barren pen also contributed to the observed levels of stereotypies.

Key words: Stereotypic behavior; Elephant; Zoo

Introduction

Stereotypies have been studied predominantly in the circus elephants and were more likely with chaining or shackling (Johnson 1990; Kiley-Worthington 1990; Schmid 1995; Gruber *et al*. 2000). Kurt and Garai (2002) observed stereotypies in 44 Sri Lankan elephants which were kept under various conditions (in temples, jungle camps, circusses and the orphanage) but chained for night. They stressed an expectation per se as a state increasing stereotypies and described the ontogeny of stereotypic movements which were predominantly to-and-fro ("parallel to body axis") in the young and then replaced by predominantly vertical movements and nodding.

There are only a few studies of stereotypies in zoo elephants which, in contrast to the majority of circus elephants, are not tethered, and thus may be expected to spend less time stereotyping. Koene (1995) studied time budgets in zoo Asiatic elephants and observed that "stereotypies were more likely to be found in small enclosures with few animals". Clubb & Mason (2002) observed stereotypies, mostly "weaving", in nine out of 21 female zoo elephants. They recorded considerable individual variation of stereotypy levels but, on the average, much higher frequency in Asiatic as compared to African elephants. Considerable individual variation of stereotypies has also been reported among zoo elephants by Rees (2004: for Asiatic elephants) and Wilson *et al*. (2004: for African elephants).

Performance of stereotyped behaviour is known to be affected by enclosure, type of restraint and repeated immobilisation. Rigid scheduling of certain animal care events influenced the expression of stereotypies in a variety of species, including elephants (Wilson *et al*. 2004). Becouse observed individual is also managed such that essential events (eg. feeding, release into an outdoor enclosure) occur at similar time of a day, I found it important to explore if there are some relationship between this events and the expression of stereotypies. So, here I present a one-year study of the stereotypic behavior in an Asiatic elephant kept single in a zoo under two alternating housing regimes.

Material and methods

This study was carried out on one Asiatic elephant female from the Municipal Zoological Garden of Wrocław. She is kept in an indoor pen and, weather permitting, released for the day to an outdoor paddock. The feeding time has been about 1300 hr (with up to one-hour delays) when she stayed indoors 24 hours per day, and at 1500 hr or later when she was let outside for the day, depending on the time of her return to the pen, whereupon she was fed.

The observations were carried out from 0900 hr until 1300 hr, for 35 days, which amounts to the total observation time of 140 hours. The observations were divided into five seven-day samples, each representing a unique combination of the season and housing: spring in the pen (S/I), spring in the paddock (S/O), early fall in the paddock (F/O), late fall in the pen (F/I), and winter in the pen (W/I). The early fall, late fall, and winter samples were taken on seven consecutive days (F/O: 20.IX-20.X, F/I: 23.X-14.XI, W/I: 02.XII-19.XII). In the spring (12.III-14.IV), when alterations between the paddock and the pen was unpredictable, the observations were carried out intermittently in order to obtain a seven-day sample for each in the paddock (S/O) and the pen (S/I).

Behaviors were scanned at constant intervals and the recording was continuous (= all occurrences) (Martin & Bateson 1993: fig. 6.1.). Recorded as stereotypic behavior were sequences of bouts of rhythmically repeated movements, together with the intervening short breaks (up to a few seconds), frequently filled with relaxed inter-bout behavior (see Results), as long as the elephant remained on the same spot. Moving to another spot ended a stereotypic sequence. Stereotypic behaviors were videotaped with a Sony CCd-TR501E camera and then analyzed in slow motion.

Statistical interpretation was based on non-parametric tests. The Friedman test, which verifies the variation in a group by the scheme of tied variables, was used to analyse the differences between medians from the sums of minutes devoted to stereotypic behaviours in each hour of observation. I applied a post hoc analysis, i.e., multiple comparisons (Nemenyi test for Friedman's ANOVA) in order to determine which periods differ in a statistically significant way.

The results were analysed using STATISTICA 6.0 package (Statsoft Inc. 2001) with respect to the total duration of stereotypic behaviours at various times of the day (min/h), the duration of single bouts of a stereotypic movement, and the incidence of each stereotypic movement throughout the entire observation period.

Results

The observed stereotypic behavior involved bouts of complex asymmetric movements (Fig. 1), which were repeated about 18 times in one bout, and much more variable, casual-looking inter-bout behavior (Fig. 2). A bout involved asymmetric nodding and body (corpus) swaying with a protraction of the right hind leg, and to-and-fro trunk swinging (Fig. 3).

Fig. 1. The studied female elephant in a bout of stereotypic movements. Note the protracted right *hind* leg

Fig. 2. The studied female elephant engaging in the inter-bout behavior (see text) of a stereotypic sequence. Note the right *foreleg* protracted and ample swaying with the trunk

In the asymmetric nodding, the head was always tilted to the left while being raised, and tilted to the right while being lowered. The body swayed to the right and slightly to the rear while the head was raised; the recovery movement of the body to the midline and slightly forwards was accompanied by lowering of the head. The body swaying was apparently effected by asymmetric bowing (possibly with some torsion) of the presacral backbone with the hindquarters remaining stationary except for a slight leaning to the right. The latter may have been facilitated by the protraction of the right hind leg, which usually occurred after a few initial movements.

The right protracted leg showed slight flexion and extension movements in concert with the right leaning and straightening of the back. The trunk was swung backward while the head was raised and forward while the head was lowered. In the paddock, the stereotypic to-and-fro movement of the trunk was combined with some tossing of sand over the back, making the trunk swinging wider and less regular than in the pen.

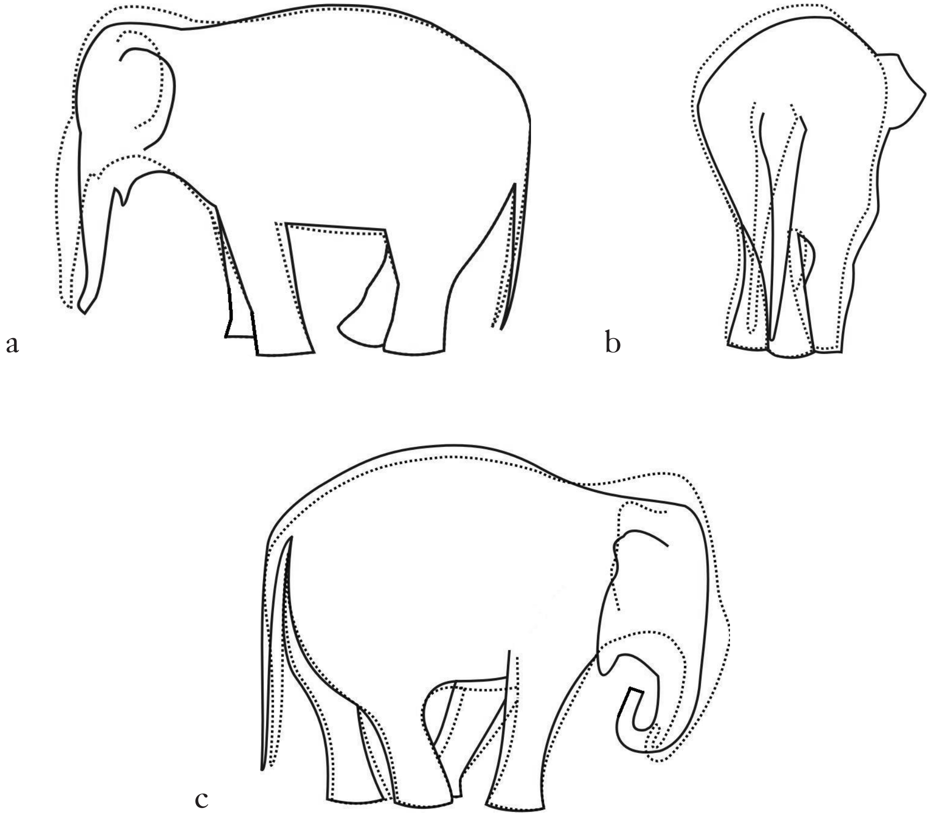

Fig. 3. Stereotypic movements performed during the bouts in left (a), rear (b), and right (c) view

The bouts of stereotypy were interrupted by variable inter-bout behavior which usually started with straightening (retraction) of the protracted hind leg and then stepping either forward or backward, followed by some turning around and, sometimes, raising and protracting the front foot.

The share of time devoted to stereotypic behavior varied significantly between the samples and was lower for the outdoor than for the indoor samples (Fig. 4). It was by far the lowest in the early fall (F/O), when the elephant was regularly released to the paddock, and much higher, close to the lowest indoor value, in the spring outdoor sample, when the releases to the paddock were irregular. There are also highly significant differences ($p= 0.01701$) between the three indoor samples. The highest levels of stereotypy occurred in the spring indoor (S/I) sample when the elephant had to stay in the pen on some days but not on others, depending on the weather. The second highest levels were observed in the late fall indoor sample (F/I), when she had to stay in the pen after a long summer period of going out to the paddock. The lowest hourly share of stereotypies performed indoors was observed in the winter (W/I), after she got used to staying in the pen all the time.

The daily dynamics of observed stereotypies was similar in all three indoor samples (S/I, F/I, W/I), with highest frequency between 1000 hr and 1300 hr. In contrast, the

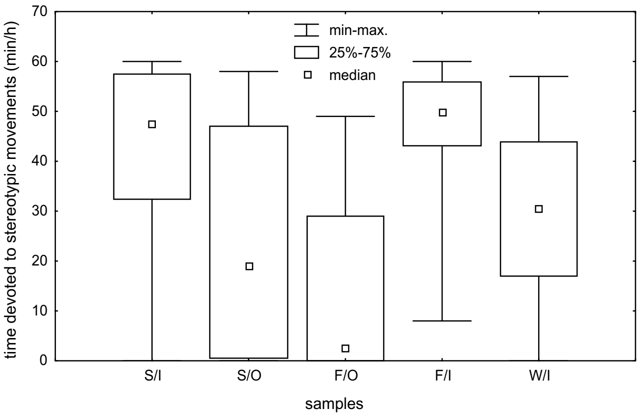

Fig. 4. The share of time devoted to stereotypic movements in each of the five seven-day samples (5x28 hours): S/I – spring/indoors, S/O – spring/outdoors, F/O – fall/outdoors, F/I – fall/indoors, W/I – winter/indoors. A post hoc analysis to Friedman's ANOVA confirmed significant differences F/O vs. F/I, S/O vs. S/I, S/I vs. F/O, and S/O vs. F/I . The module of difference was greater than C_{kw} value in all these samples

two outdoor samples differ dramatically in this respect. In the spring (S/O), when the days outdoors alternated with the days indoors, the maximum amount of time spent on stereotypies was between 1200 hr and 1300 hr, that is, immediately before the feeding time on the indoor schedule (Table 1). In the fall (F/O), after the entire summer of spending daytime outdoors, the maximum hourly median value was between 1400 hr and 1500 hr, that is, within one hour immediately preceding the return to the pen and feeding. The difference between the two outdoor samples in the amount of stereotypies from the fourth hour of observation (1200-1300 hr) is statistically significant (Wilcoxon signed ranks test: Z=2.201, p=0.027709).

Table 1. Time (medians, in minutes) used for stereotypic sequences by the female elephant indoors in the spring (S/I), late fall (F/I), and winter (W/I) and outdoors in the spring (S/O) and early fall (F/O). Based on Friedman's ANOVA, all differences between samples are highly significant (p«0,000)

Sample	9:00-10:00	10:00-11:00	11:00-12:00	12:00-13:00*
S/I	28	58	54	48
F/I	21	48	53	51
W/I	1	19	51	40
S/O	0	39	19	51
F/O	1	0	16	18

Discussion and conclusions

Most probably, several factors contributed to the observed high levels of stereotypy. What this data suggest is the impact of changes in the management schedule, which occurred within observation period, and of the confinement to a barren indoor pen through the winter. The highest levels of stereotypic behavior in the spring (S/I) and fall (F/I) indoor samples occurred concomitant with (S/I) or after (F/I) the changes of both the housing regime and feeding schedule. This suggests an aggravating influence of the unfulfilled expectation of being released. Also, the surge of stereotypies before the indoor feeding time (1300 hr) in the spring outdoor sample (Table 1) is best explained by the expectation of food which was delivered on this hour throughout the winter. There is good evidence that an expectation of feeding (e.g., Kurt & Hartl 1995; Friend 1999; Rees 2004) or other events (Friend 1999; Kurt & Garai 2002) may evoke stereotypies in captive elephants, probably because a captive individual has nothing to do about it due to restraint, artificial environment and/or its own impairment.

No changes of management schedule were at play during the summer, ending with early fall outdoor sample (F/O), and during the winter indoor stay (W/I). A comparison of samples from the two stable periods (Table 1) with dramatically different housing regimes suggests that the confinement to a small, barren indoor space contributed to the observed levels of stereotypies in the winter indoor sample.

The observed high frequency of stereotypies seems to be a compound result of (1) single housing with little or no environmental enrichment; and (2) imposed changes in daily routine, which raised expectations that were fulfilled with a delay (feeding outdoors in the spring) or not at all (release to the paddock on some spring days and in the late fall).

There are also two novelties in comparison to published descriptions in the stereotypic behavior of elephants (Kiley-Worthington 1990; Kurt & Hartl 1995; Friend 1999; Rees 2004). One is a clear distinction between the bouts and the inter-bout behavior, and the other is a pronounced asymmetry of the stereotypic bout movements, which makes such descriptive terms as weaving and nodding inaccurate without a qualifier. While this paper present interpretations of a behavior observed in just one individual would not be warranted, I think that further detailed descriptions of elephant stereotypies will help compare them to natural behaviors and thus better explain their causation.

Acknowledgements. I gratefully acknowledge a great cooperation of the Wrocław Zoo personnel, Dr. Antoni Gucwiński (Director), Mr. Mirosław Piasecki (Head of the Ungulate Section), Mrs. Ewa Piasecka (Senior Assistant for Education), and other staffers. I also thank my colleague, Dr. L. Pasko for expert advice in statistics and Prof. Andrzej Elżanowski for his supervision, guidance and support throughout this project.

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The distribution and inbreeding level in Dalmatian Pelican population (*Pelecanus crispus*, Bruch, 1832)

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Abstract: Although, as it already mentioned, Dalmatian Pelicans have been kept in zoological gardens over many decades, since the 80's of twenty century an intensive breeding and protection of the species began. Unfortunately, the population is relatively small. To our knowledge, no results on inbreeding rate in Dalmatian pelicans have been available in literature. The objective of this contribution was to estimate an inbreeding level in Dalmatian Pelican population in context its distribution around the world. Records of 889 Dalmatian Pelicans (extracted from SPARKS computer programme of the Dalmatian Pelican EEP studbook by Piotr Ćwiertnia - edition of 01.06.2005) were analysed. The birds studied hatched (in zoological gardens) or caught from wild between the years 1957-2005. Two approaches have been employed to estimate inbreeding coefficients (with and without pedigree information). Only 26 registered as inbred birds were hatched in three zoos (Vienna, Prague and Poznan). By far the largest share in captive population have birds kept in just two French collections. The individuals in both zoos were not pedigreed. The hypothetical inbreeding for these birds, yielded 0.13 for Villars and 0.39 for Mullhause.

Key words: Dalmatian pelican, inbreeding rate, captive breeding, population distribution

Introduction

The Dalmatian pelican distribution covers parts of southern Europe and vast expanses of Asia (Crivelli *et al.* 1991, 1997). During the XIX and XX century the numbers of these birds begin to fall drastically, mostly due to uncontrolled hunting and habitat alternation (Crivelli, 1987 after Reiser and Fuhrer, 1896; Crivelli i Vizi, 1981; Crivelli, 1984). In captivity first breeding was recorded at 1961 year at Tierpark Berlin (Grummt, 1984) regular breeding results have been obtained in the middle 80's. In the view of potential importance of captive population to conservation of this species the European Endangered Species Program (EEP) had been initiated. Although, as it already mentioned, Dalmatian Pelicans have been kept in zoological gardens over many decades, Since the 80's of twenty century an intensive breeding at captivity (Ćwiertnia 2001). Unfortunately, the population is relatively small. Therefore, an inbreeding rate has been registered. A number of investigations was conducted on inbreeding rate and its effects in animal populations (Princee, 1998; Szwaczkowski *et al*., 2004). To our knowledge, no results on inbreeding rate in Dalmatian pelicans have been available in literature.

The objective of this contribution was to estimate an inbreeding level in Dalmatian Pelican population in context its distribution around the world.

Material and methods

Records of 889 Dalmatian Pelicans (extracted from the Dalmatian Pelican EEP studbook by Piotr Ćwiertnia) - edition of 31.12.2004) were analysed. The birds studied hatched (in zoological gardens) or caught from wild between the years 1957-2004. More details on number of individuals studied over time are given in Fig. 1. Sex structure of the population in chosen zoological gardens is listed in Fig. 2. Sex of relative large number of individuals (57% of total population) is known.

Majority of birds (73%) has unknown both parents whereas only 25% individuals have known both parents. Only one parent is unknown for 2% birds. Length of life were recorded for 370 birds. It mainly influenced by large longevity of pelicans kept in captive breeding. Lifespan of some individuals achieves 40 years. In consequences, some unrecorded individuals are likely still living. Hence, the classical analysis of relationship between inbreeding rate and longevity seems to rather difficult in the population studied.

For above mentioned reasons, two approaches have been employed to estimate inbreeding coefficients. First one is based on pedigree data, according to classical formulae given by Wright

$$F_X = \frac{1}{2}\sum_{ij}(\frac{1}{2})^{n_{ij}}(1+F_{M_i})$$

(1921):

where: F_x – inbreeding coefficient of individual X; F_{Mi} – inbreeding coefficient of common ancestor M_i; n – number of generations between parents of individual X via common ancestor. The computation was performed for 222 individuals with complete pedigree data.

Average hypothetical inbreeding coefficient was estimated based on formulae described by Wright (1931):

$$\Delta F = \frac{1}{8N_s} + \frac{1}{8N_d}$$

where: N_s – number of sires, N_d – number of dams.

This formulae was used within generations for two data sets: */ all males and females, and **/ only sires and dams. These computations were performed for four zoological gardens (Villars les Dombes, Mulhouse, Poznan and Prague).

Results and discussion

At the moment, Dalmatian pelicans are kept in 22 (?) zoological gardens. Generally, the subpopulations are considerably diversified. It resulted from management systems and genetic variability. Distribution of Dalmatian Pelican subpopulation (number of males and females) in five more important zoos is presented on Fig. 3. The greatest population of hatched birds were in Villars les Dombes and Mullhouse. It should be noted that Mulhouse's pelicans are progeny (generation F1) of Dombes' birds.

Estimated inbreeding coefficients by Wright's method included pedigree data are listed in Table 1.

Table 1. Average inbreeding level for Dalmatian pelicans in three zoological gardens

Zoo	Number of inbred birds	Average inbreeding coefficient
Poznan	9	0.250
Prague	16	0.275
Vienna	1	0.250

Only 26 inbred birds kept in three zoos (Vienna, Prague and Poznan) were registered. The individuals (8 females, 8 males and 10 individuals with unknown sex) were hatched in 1999-2000. As it already mentioned the reported number of inbred individuals was determined by limited pedigree information. Average inbreeding coefficient of total population is 0.77. However, the value is underestimated due to incomplete pedigree data.

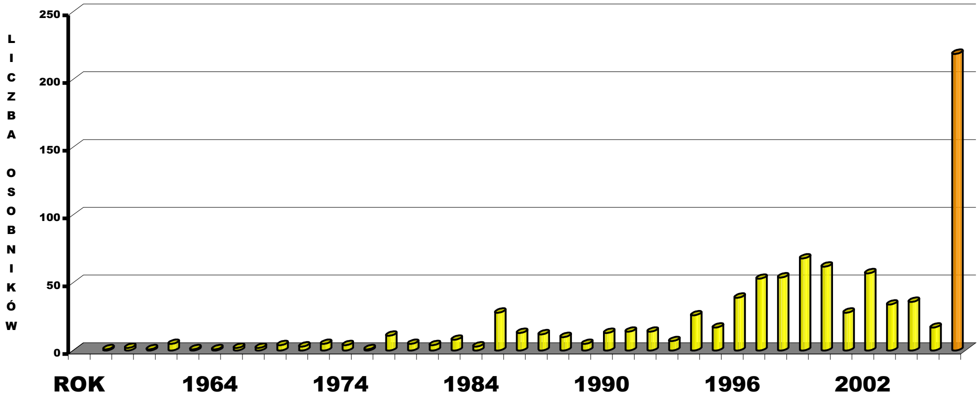

Figure 1. Number of individuals hatched in consecutive years

By contrast to above approach, second method based only on number of males and females were also employed to estimate inbreeding level. The hypothetical levels of inbreeding over generations within four zoos were given on Figure 3. Variability of inbreeding rate was observed among both zoos and generations. The estimates of inbreeding level obtained for parents are considerably higher than ones computed for all individuals. It should be recall that the formulae omitted pedigree information.

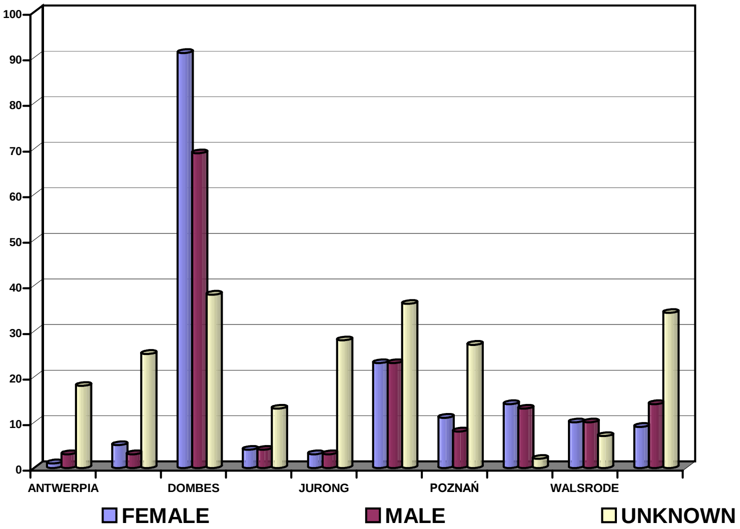

Figure 2. Number of males and females in chosen zoological gardens
(może most important?? Albo cos w tym stylu?)

As it already mentioned , by far the largest share in captive population have birds kept in just two French collections. The individuals in both zoos were not pedigreed. The hypothetical inbreeding for these birds, yielded 0.13 for Villars and 0.39 for Mullhause. This comparatively high values may not be very worrying because due to high philipatry of the species (Catsadorakis and Crivelli, 2001). In general, there are

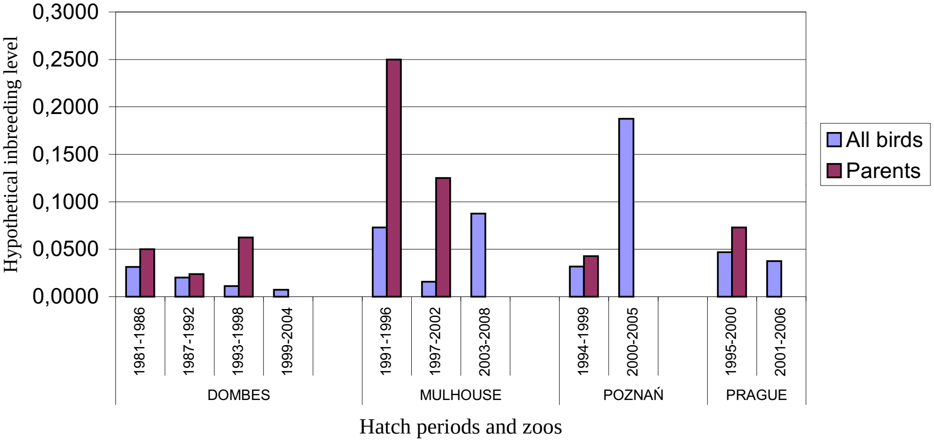

Figure 3. Hipothetical inbreeding level in of chosen zoological gardens

prominent differences in size of different subpopulations. This factor undoubtedly reflects the level of inbreeding within different groups.

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Sexing of eastern white pelican (*Pelecanus onocrotalus*) based on biometric measurements

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Abstract: We examined sexual size dimorphism of Eastern White Pelicans (*Pelecanus onocrotalus*). Investigation were carried out in Poznań Zoological Garden (Poland). For adult and juvenile individuals culmen length was taken on late Autumn (1993-2003) (N=46). Very detailed investigation were carried on chicks reared, during 1998, 1999 and 2002 years. Totally body mass was taken for 20 birds, culmen length for 12, and corpus length and wing chord for 9 birds. Sex determination on culmen length is possible in age 21 weeks. For younger chicks better method for sexing is use body mass, which allow in age 5 weeks, on sexing every second chick.

Key words: Eastern White Pelican; *Pelecanus onocrotalus*; sex determination; Biometry; Zoo

Introduction

The identification of the sex of birds is of fundamental importance. Most seabirds are sexually monochromatic and it can be difficult to sex individuals. Relatively easy, non-lethal and non-invasive techniques are useful not only for captive management of endangered species, but also for aspects of avian biology, where results are divided into sexes. Since the possibility of sex determination by DNA analysis appeared it is possible to identify sex without harming the bird. But this method is time consuming The attempt to recognize sexes of the pelicans based by culmen length are known (Dorr *et al*. 2005, Grummt, 1984). Sexing of Eastern White Pelicans (*Pelecanus onocrotalus*), is easy but possible for birds which stoped their growth , and usually it is done at second year of life.

Aim of our investigation was to find age whan sexing by culmen lenght is possible, and find another way to sexing younger chicks.

Materials and methods

Investigations were carried out during ten years (1993-2003).

For adult and juvenile individuals culmen length was taken on late Autumn (N=46). Very detailed investigation were carried on on chicks reared, during years: 1998, 1999 and 2002. At 1998 year we have have recorded body mass of 8 chicks up to chicks reached age of one month. Three of them were males and one females. For four chicks sex is unknown (three died). Measurements were taken to the nearest 0.05kg with a Pesola spring scale.

During 1999 year we have investigated 9 Great White Pelicans reared at Poznań zoo two of them were males (one hand reared and one reared by fosters *P. onocrotalus*), and 6 females (two reared by parents and four by hand). One chick died at age 7 days (unknown sex).

Measurements were taken every week on all birds: culmen length (CULM), (straight line down the centre of the bill from the hook to the skin at the base). Wing chord (WCH), (wrist joint to the tip of the most distal point of wing- without feathers) corpus length (CL), (from thorecicol 1 (Th1) up to coccigeal 1 (Cc1)). Measured were taken by vernier caliper, to the nearest 1mm. (Fig. 1).

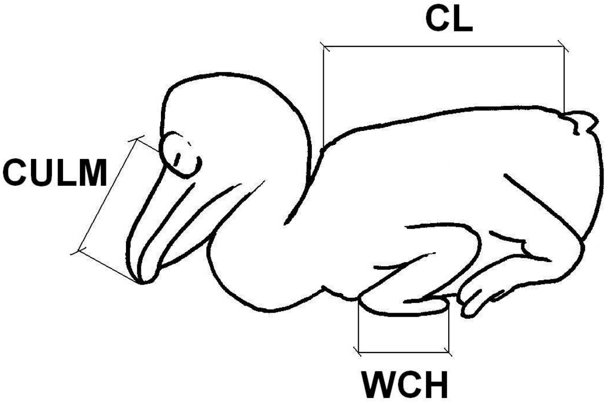

Fig. 1. Mathod of measurement taking on pelicans chicks. CULM – culmen length, WCH – wing chord, CL – corpus length

At the same time body mass was recorded. Body mass was measured to the nearest 0.05kg (to age two weeks), and 0.2 kg with a Pesola spring scale. Chick reared by parents or fosters were measured at every visit at colony. Regular measurements were taken to age 13 weeks (for hand reared) and 5 weeks (for parents or fosters reared chicks). After this age chicks kept distance to keepers and measurements were irregularly. After age 21 weeks there were no visible different in body measurement. Additionally data about chick's development were noted.

During 2002 were measured three, hand reared Great white pelicans (two males and one female), but only culmen length (up to age 22 weeks), and body mass (to 18 weeks) were taken. Measurements were taken in similar way as in 1999 year.

Sexes for investigation were recognized on gonadal ispection during autopsy or by breeding behavior. Chicks were sexed by culmen length.

Result

Culmen length for adult birds showed differences among sexes. Always males bill was longer than females and there were no exceptions (males bill length: mean= 42.03cm., SD= 1.85cm., maximum= 44.5cm., minimum= 38cm., and females bill length: mean= 31.38cm., SD= 2.11cm., maximum= 34.1cm., minimum= 28cm.).

Repeated measurement showed that culmen length grew up for individuals younger than 6 month (N= 6), after this age culmen length have no changes even after period of 10 years.

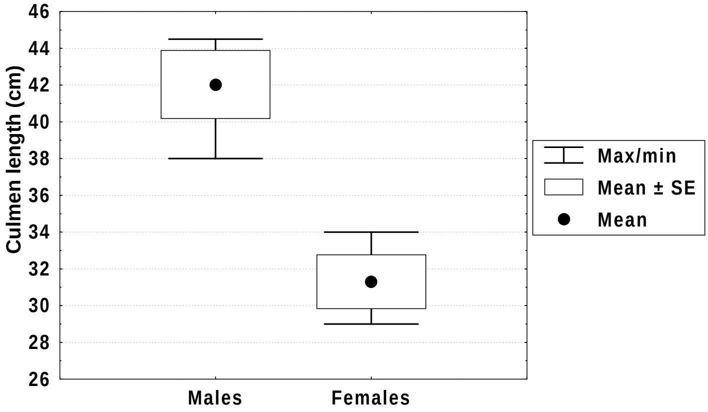

Fig. 2. Culmen length of adult males (N=12) and females (N=15) reared at Poznan zoo during 1993-2003 years

Chicks culmen length grow up contentiously up to age abut 21 weeks when growing rapidly stop. Good visible different among sexes appear at age 11 weeks.

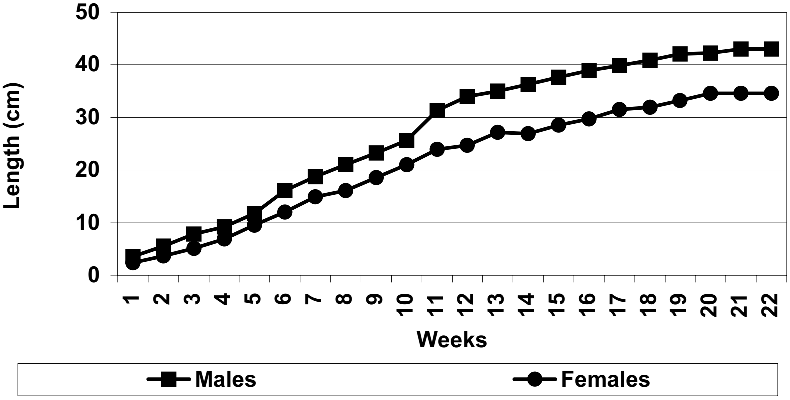

Fig. 3. Changes in culmen length of males (N=4) and females (N=8) reared at Poznań zoo during 1999 and 2002 year

Growing rate of chicks wing chord and body length for females and males are similar although body length grew up more rapidly during first six weeks of life, and stop in age 8 weeks. On the other hand wing chord start rapid growing later, at age 5 weeks and finishing in age 10 weeks.

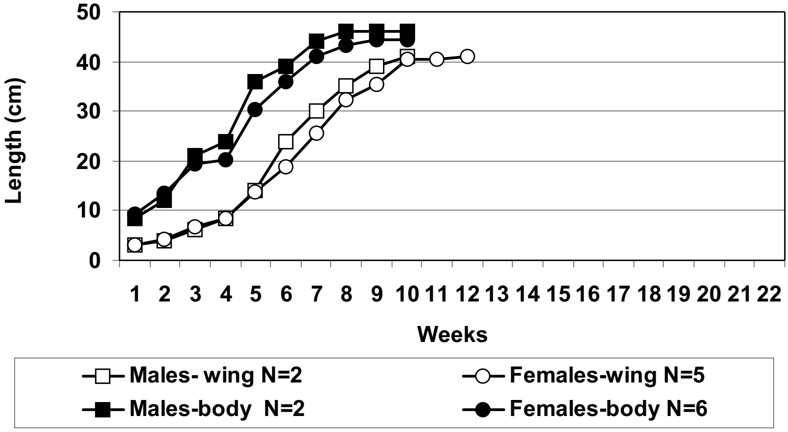

Fig. 4. Changes in wing chord and body length of males and females reared at Poznan zoo during 1999 year

Different among sexes in chicks body mass seems as high, but Standard deviation is also high and some females can be bigger than medium male. On the other hand males can be lower than females. After maximum at age 10 weeks body mass drop for about half kilo.

Growth rate of one parent reared male at the first days of life increase much more rapidly than other chick, but after few days this different has decreased.

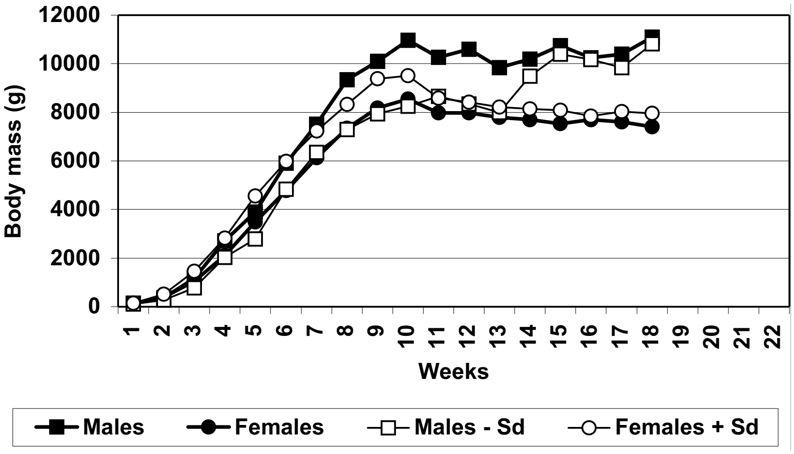

Fig. 5. Changes in body mass of males (N=7) and females (N=10) reared at Poznan zoo during years 1998, 1999 and 2002

Discussion

Sex determination. At sexually monochromatic species it is always difficult. Similar is at Great White Pelican. Investigation carried out on American White Pelicans (*P. erythrorhynchos*). showed that from many measurement only culmen length is good for sexing (Dorr *et al.* 2005) . Similar is at Eastern White Pelicans, where males' culmen reach 38 cm or more, and female is below 36 cm. This results standing in agreement to other authors (Dementiev and Gladkov 1951; Grummt 1984; Grummt 1984 after: Ali and Ripley 1968; Bauer *et al*. 1966; Hartert 1912-21; Delacour 1931; Portman 1937). Aalthough we haven't found any exceptions, Chaplin and Amadon (1950) have found male with shorter bill (34.7 cm.) and Romashova (1994) has found culmen length for males is 35-47cm (average 43,2cm) and for females 30-46cm (average 34cm).

This method is very useful in age of 21 weeks, when bill stop growing, We could expect that possibility of sexing is earlier, but although figure 4 don't suggest it we have found females with similar bills' longevity as males.

Culmen length is very stable and in some cases can be use for individual identification.

Result suggest that better method of sexing at early age is body mass. In age 5 weeks (we choose this age for complete data), this method allow on sexing every second chick. In this method male is birds whose body mass is over Medium females body mass + Standard Deviation (SD). Similar female is birds with body mass lower than medium body mass for males – Standard Deviation.

In this age growing rate for hand and parent reared chick were similar, although it is soon after beginning of food limitation by parents.

We haven't also found different in grow rate from chick reared at Praha zoo (Pithart *et al.* 1991) and observed by Din and Eltringham (1974) in situ.

Body mass, and wing chord stop their growing in age 10 weeks, it is far after strong limitation of parental care, which occurred in age 7 weeks, and before fledging time, which for Great White pelican is estimated on 2,5 month (Romashova, 1994) or 100-105 days (Dementiev and Gladkov, 1951).

Discriminant analysis, although in low number investigated birds not statistical significant, suggest that the main measurement for sexing in early age could be body length, but further investigation are needed.

Conclusion

1. Sexing by culmen length is possible in age 21 weeks (males culmen >38 cm., females culmen < 36 cm.)
2. Younger chicks can be sexed by body mass. In age 5 weeks it allow on sexing every second chick.
3. Culmen length is very stable and can be used for identification individuals.

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Developing the research potential of zoos and aquaria

Gordon McGregor Reid

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I must first express my thanks to the organisers for inviting me to give the opening address at this the 3rd research-themed conference 'Animals, Zoos and Conservation'. I, along with all the other participants, greatly appreciate the work put in by staff of the Zoological Gardens of Poznan and of the Adam Mickiewicz Insitute of Systematic Zoology, Poznan. In particular, I should thank Drs Piotr Cwiertnia and Radoslaw Ratajszczak of Poznan Zoo for being such wonderful hosts. As active members of the European Association of Zoos and Aquaria (EAZA), the organisers have developed an interesting and exciting programme of talks. In supporting this conference, Poznan Zoo is leading the way in demonstrating to the wider zoo community the high value of science and research.

Overview

For my own contribution, I have been asked to address the subject of 'Developing the Research Potential of Zoos and Aquaria'.

Science is now part of the essential approach to modern biodiversity conservation in a zoo and aquarium context. Animal husbandry and welfare in zoos can also greatly benefit from the scientific approach. However, there is a major task ahead to gain wider and deeper acceptance of research in the zoo community. Indeed, active engagement in research and the dissemination of results are necessary to spread the word and maximise the benefits.

Evolution of Science

For all sorts of practical reasons, humans have always had to deal with biological realities. For example, food, clothing and shelter are often derived from animals and plants. Without them, survival is impossible. The treatment of ailments too, has been a pressing biological consideration, again fundamentally relating to well-being and survival of people, or the survival of the animals that they depend on.

In pre-industrial 'stone age' societies *ca* 10,000 years ago unsophisticated 'biological' knowledge will have been passed on by word of mouth – the oral tradition in communication. However, a problem at that time (persisting to the present) was determining what forms a basis for knowledge, and whether we can make progress through rational enquiry as opposed to superstition. 'That man can interrogate as well as observe nature was a lesson slowly learned in his evolution' (Sir William Osler, *Aphorisms from his Bedside Teaching and Writings*).

Written communication is a fundamental step in science – not always practised, even in the present day! How many of us in the zoo and aquarium community know something original about the care, biology or conservation of our animals or plants, and yet have never written it down?

According to one simple definition 'Science is organised knowledge' (Herbert Spencer, *Essays on Education*). Written accounts are the first necessary step in developing a challengeable yet stable foundation for knowledge. Perhaps the first attempt to organise and compile knowledge and express it in writing began in Babylon – one of the great early civilizations, now the site of contemporary Iraq. The Code of Hammurabi *ca* 3,926 BP *(*1,920 BC) certainly represents the best known early example of knowledge laid out systematically by categories. Accounts of anatomy, ailments and medical remedies are contained in the Code. This represents valuable wisdom passed down through the generations, but for the first time consolidated in a permanent form. Nevertheless, the Code is permeated with supernatural ideas and (to the modern scientific mind) irrational thought.

A rather more rational approach to understanding the world and the universe began in Ionian Greece on the shores of the Aegean Sea (in what is now Turkey). Rather than rely on supernatural explanations, there was a growing understanding that there were patterns in nature, some of them predictable. From this, highly reliable general statements or 'natural laws' could be arrived at. Also, the idea of predicting 'cause and effect' began to take hold. It was Alcamaeon (who flourished *ca* 500 BC) who said: 'Men perish because they cannot join the beginning with the end'. Alcamaeon stands out among the early Greek philosopher-scientists in promoting rationalism.

However, it is Aristotle (born 384 BC) who must be regarded as the 'Founding Father' of zoology – the scientific study of animals. He was the first person to accurately describe the appearance and behaviour of animals, to name them and include them in a logical, systematic classification scheme. This was arranged from the most basic life forms to the most complex, and so laid the early foundations for an understanding of evolution. Certainly, Aristotle was 2000 years in advance of his time because he was the first to recognise that dolphins are akin to placental land mammals rather than fish. Despite this, the idea that dolphins were a kind of fish persisted throughout the classical period to medieval times. Aristotle in his published work *On the Generation of Animals* (translated by Arthur Platt) also laid the foundations for studies in reproductive biology. During this period in the development of rationalism, there was also the foundation of the first wildlife gardens with mammals, birds, and fishes in ponds. For example, Gustave Loisel in his *Histoire des Menageries de l'Antiquite a nos Jours* (Paris, 1912) notes the early menagerie in the *Jardin d'Acclimatation* of the 18th Egyptian Dynasty 3,568-3,334 years BP (*ca* 1562-1328 BC).

Modern Science

Charles Sanders Peirce proposed that: 'There is one thing even more vital to science than intelligent methods; and that is the sincere desire to find out the truth, whatever it may be' (collected papers of Charles Sanders Peirce, vol. V). If we move forward to contemporary science and research in zoos and aquariums, then the same general principles apply. A sincere endeavour to determine the 'truth' underpins zoological science. However, in saying this we recognise that the making and breaking of hypotheses in the course of history changes what we recognise as being the 'scientific truth' at any one point in time. Fundamentally, modern science is the creation of a body of knowledge based on accurate observation and experiment. This body of knowledge is continually evolving and improving. Science does not rely on and is not supported by myths, rumours, anecdote, superstition or theology. Research is the process used to assemble and test knowledge with precise observation and a rigorous scientific method.

Research policy and strategy

For individual zoos and aquaria there is a statutory requirement to conduct research – which is embodied in the European Zoo Directive (March 1999). This has been transformed into succinct guidelines in some countries, e.g. by DEFRA, the Zoo Licensing Authority in the UK (www.defra.gov.uk); and by an associated body the Zoos Forum (http://www.defra.gov.uk/wildlife-countryside/gwd/zoosforum/index.htm). In any event, the research potential for zoos and aquaria is huge. All zoos and aquaria should prepare and adopt a written research policy and strategy relating to the natural interests, challenges and opportunities reflected in their institution. In forging this document, zoos and aquaria can adopt relevant research guidelines that have already been published. They can, for example, follow the scientific guidelines embodied in the Science chapter of the *World Zoo & Aquarium Conservation Strategy* (World Association of Zoos & Aquariums, 2005) and also refer to the *EAZA Research Strategy* (publication pending, 2006).

Inevitably, much zoo research will be applied to high priority problems in conservation, welfare and veterinary care. Research should typically strive to be quantitative, as distinct from being simply qualitative. For example, basic counts, weights and measurements can support research in various areas including animal identification (taxonomy), reproductive biology, communicable diseases (zoonoses) and life history studies. A policy to conduct applied research across the boundaries of hitherto separate disciplines may yield major new insights, e.g. studies in nutrition can usefully interlink with studies in reproductive biology to ascertain causes and cures for fecundity problems. While mainstream applied research in conservation and welfare is a priority, it is important to ensure that 'general research' opportunities are contained in the policy and strategy. This general research need not necessarily be designed to have immediate practical outcomes or be focused on traditional areas of biology. Such 'blue sky' research can bring about major strategic benefits because it can be argued that: 'Every great advance in science has issued from a new audacity of imagination' (John Dewey, *The Quest for Certainty*). Studies on plants should be included, as appropriate. Plants are items of food and 'furniture' or a habitat for many animals and are important topics in their own right for research and conservation. In addition to using well tried and tested methods, there is the growing opportunity to use new technology where appropriate, e.g. electro-ejaculation, the cryopreservation of sperm, or DNA analysis.

Ethics and Welfare Policy

Individual zoos and aquaria need to prepare and adopt a written Ethics and Welfare Policy to run in conjunction with the Research Policy & Strategy. This document should take into account ethical, legal, social and environmental issues (ELSE), e.g. animal acquisition or disposal, permits, experimental protocols, position statement on biotechnology, benefit sharing agreements with local people in an outreach research project. Again, there is the opportunity to adopt or subscribe to higher level policies or guidelines such as those of EAZA and WAZA. It is important to stress that zoo research need not be invasive or particularly intrusive. Valuable research results can be obtained simply by observing animals. Similarly, physiological data on stress in animals can be obtained from analysis of faecal hormones. All animals die eventually, no matter how well they are cared for, and analysis of post-mortem material can yield valuable results. Overall, zoo research should be benign, non-invasive and non-intrusive. There needs to be a valid reason to depart from these principles. There is also a need to have an ethical review process, perhaps involving an independent scientific advisory board to scrutinise the research proposals, methods and results. As well as senior scientists and veterinarians it is important to ensure that keepers and curators are included on this committee and also that external lay people have an opportunity to contribute their views. Certainly, there needs to be a balance of sexes, disciplines, expertise and viewpoints. For particular research issues or projects there is the opportunity for the zoo or aquarium to host debates or other structured meetings.

Implementing the Research Strategy

To move forward in practical terms it is first necessary to create an institutional budget for research and to grow this each year. It need not be a large amount of money. The most important thing is to make a start! To increase the resource base, zoos and aquaria need to develop relationships, informal or formal, with other zoos or aquaria and with external institutions engaged in research. If strategies and priorities coincide, it should be possible to develop a zoo consortium or develop research funding partnerships with other organisations such as universities, colleges, museums, research institutions, botanical gardens and wildlife agencies (see below). Certainly, these are promising targets in relationship development.

Other simple steps can be taken to promote research including establishment of basic facilities and capabilities, e.g. a simple laboratory with a sink, bench and a microscope for analysing samples. Failing this, a zoo could obtain agreement to use the laboratory of a partner university or museum. Facilities alone cannot produce research results. The zoo management should provide encouragement, time and other resources so that staff can organise themselves to conduct research, however basic. This might be to support a part-time study programme for a keeper undertaking a university degree by research. A big step forward in the implementation of a research strategy comes with the employment of full-time scientists based in the zoo (e.g. behaviourists, nutritionists, experts in animal husbandry, veterinary researchers, laboratory technicians, scientific officers). A first appointment could be part-time with a view to eventually establishing a full-time position.

Accurate record keeping is at the heart of good science. The new, global computerised Zoological Information Management System (ISIS-ZIMS) offers major research opportunities, including for curatorial and keeping staff. ZIMS compiles and analyses records of 'everything' - from basic identification, studbooks and population genetics, to reproductive success, nutrition, environmental enrichment and health, to release programmes in the field. Staff can be empowered to gather and input the available institutional data. Animal samples, records and research results need to be made widely available. Good science prospers in open environments where there is free exchange of information and materials. Valuable data need to be shared within the zoo or aquarium itself and also with partner institutions.

In order to fulfil the full research potential of zoos there is now a need (well-expressed in the *World Zoo and Aquarium Conservation Strategy*) to promote research in nature (i.e. *in situ*) as well as research in the home institution (i.e. *ex situ*). There is often a beneficial 'multiplier effect' in terms of cost and benefit when money from European zoos is spent in the habitat countries. Sometimes both *in situ* and *ex situ* activities can be organised to complement and inform each other. In my own institution Chester Zoo (the North of England Zoological Society) my colleague Mark Pilgrim is conducting important doctoral research on the systematic biology of Amazon parrots (the *Amazona lilacina* species complex). The precise status of individual species or subspecies in this complex is currently unclear. Given that some Amazon parrot taxa are included in the IUCN *Red List* (and others are not, but probably should be included) it is imperative to resolve this problem soon. The research approach adopted by Mark Pilgrim involves studies of Amazon parrots in the wild coupled with specimen-based research conducted in zoos, universities and museums. The specimens are both living (from which DNA samples are obtained) and preserved (museum registered study skins).

In situ or field research can be conducted locally as well as abroad. Indeed, zoos and aquaria should develop a significant local component to their research strategy. At Chester Zoo there are several research *cum* conservation projects currently being conducted on local mammals, birds, reptiles, amphibians, invertebrates and plants. A reintroduction and monitoring scheme for harvest mouse (*Micromys minutus*) has, in particular, gained public interest and support and attracted unpaid volunteer helpers.

Funding for research

At the moment, under the European Zoo Directive individual institutions do not receive any very intense statutory scrutiny of their scientific endeavours and research output. In future, it is likely that zoos will eventually have to engage in the sort of research assessment exercises (RAI's) as our university colleagues. Of course the outcome of such exercises can determine the strategic opportunities for institutions, including access to public funding. For those zoos and aquaria that are not presently in a position to develop substantial internal research programmes and projects, there remains the opportunity to raise and contribute funds for the work of others, or work in partnership to gain co-funding. For example, whole-organism biology is often underfunded in the university and museum sector. Various university or museums would benefit greatly from comparatively small amounts of partnership funding, e.g. to support taxonomic studies on amphibians and the gathering of life history data.

A externally funded PhD studentship on the foregoing lines (developed in partnership between the University of Manchester and the North of England Zoological Society), provides a unique and timely opportunity to conduct amphibian research of direct conservation benefit and application (Kevin Buley, personal communication). The University of Manchester are working with NEZS on a CASE (Co-operative Awards in Sciences of the Environment) partnership to funding a PhD studentship. The CASE scheme aims to promote partnerships between universities and other bodies, enhancing the training received by students who will gain first-hand experience of work outside of a purely academic environment. Focussing on an *ex situ* conservation population of an endangered neo-tropical tree frog – the splendid leaf frog *Agalychnis* (*Cruziohyla*) *calcarifer* – this CASE project will explore how modifications of diet, light and their interaction effect development, morphology, behaviour and fitness.

Manchester Museum (which is part of Manchester University) holds the only *ex situ* population of the splendid leaf frog. Vivarium bred specimens have so far failed to exhibit the bright colours found in wild stock. The effects of vitamins (carotenoids) in the diet are being investigated in a small scale study which utilises the expertise of herpetological staff in the zoo. Preliminary results strongly suggest that carotenoids may be substantially implicated in fecundity, enhanced fertility and overall health of female animals. A further, more in-depth study should provide greater insight into the general nutritional value of carotenoids in amphibians and so advance our general understanding of how diet and environment interact to influence reproduction, intra-specific communication and health. Clearly, such research results are likely to be applicable to other species of endangered amphibians.

Research facilities can be integrated into exhibits, again using a partnership funding approach. For example, a research observation hide has been incorporated into a 'miniature monkeys' (Tamarin and Marmoset) exhibit, recently completed at Chester Zoo. This feature was planned and developed in conjunction with the University of Chester, Department of Psychology, and the hide was paid for by the university. To publicise this scientific partnership we invited distinguished researcher and media personality Professor Lord Robert Winston to preside over the public opening. The marketing of research through such public relations exercises is very important.

Publication of Research

Science is a public process and it can only move forward on the strength of easily accessible published results (preferably peer-reviewed). Increasingly, web-based publication is a feature of peer-reviewed and other journals. Setting up e-mail groups for distributing and discussing research results is worthwhile. Also, the simple act of photocopying and sharing personal research notes or observations may contribute greatly to a research project. However communicated, research results need to be made available on a timely basis.

Zoos and aquaria should work to build up a basic research library and archive. This would serve as a working 'drop in' centre which curators, veterinarians, keepers, external students and other researchers can visit, consult with the literature and file reports. External academic partners may be happy to contribute books, papers and other material to support the library.

Research Training

One of the most important potential roles for zoos and aquaria is to act as research training providers for schools, through university, to post-doctoral level. Research awareness can start with young children in a zoo education centre. Such awareness exercises can take place *ex situ* or *in situ*, at home or abroad. Zoo staff should wherever possible be supported to train in science-based courses in animal management through to research degrees. Zoos can co-organise university level courses, e.g. Chester Zoo supports courses for a BSc in Conservation Medicine and an MSc in Conservation Biology – co-organised with the University of Liverpool and Manchester Metropolitan University, respectively. Academically qualified zoo staff can reinforce relationships by becoming part-time university lecturers, joining faculty boards, assisting in course development, supervising research students and so forth.

Even with modest lecture room or classroom facilities, zoos can host and organise lectures or symposia on scientific topics; or at least utilise the facilities of a partner to the same effect. Zoos and aquaria can build up a scientific membership by subscriptions (sometimes termed 'Scientific Fellows') and also attract research volunteers for appropriate projects.

Public Communication of Science

Living institutions need to develop communication programmes in the specialised area of the public understanding of science, education and technology (PUSET). Zoos and aquaria (alongside natural history departments in museums) are the most obvious targets for public enquiries. If someone wants to make a scientific enquiry about an animal, the zoo is often the first 'port of call' and many receive such enquiries on a daily basis. This should not be viewed as an inconvenience but rather as an asset base to be developed. With their massive visitor numbers (125 million each year in Europe alone) zoos and aquaria are uniquely placed to engage in a scientific dialogue with the general public.

Combating scientific stereotypes is a big issue for the public understanding of science in general and for people actually employed or engaged in science-based activities in zoos and aquariums. There are, then, both external and internal issues in communication:

1. Progressing science to the advantage of animals (individuals, populations and species) and also the institution, without incurring an adverse response from the outside world. That is to say we need to demonstrate that zoological science generally is, or can be, a 'good thing'.
2. Gaining recognition within any one institution that science is necessary, valuable and worthwhile, and produces practical benefits. That is to say we need to demonstrate scientific needs and benefits to our own staff.

Sometimes the first person to be persuaded is the zoo director who may not have a background in science and who may think that research is high flown, remote, irrelevant and costly and also generates public relations problems.

One big area for potential public relations difficulties is in animal welfare and animal rights. Zoos are often dependent for their income on visitors through the gate, and so positive public perceptions are crucial to their existence. The university sector in the UK is currently under siege from animal rights activists against experimental research in laboratories. Animal rights protestors also target zoos and aquariums from time to time, based in part on the notions that it is cruel to keep animals in captivity and that research is inevitably unnecessary and inhumane. The image of white-coated 'mad scientists' doing unspeakable things to animals upsets many people and can attract well-intentioned but misconceived protest in a zoo context.

In fact, real zoo and aquarium research typically does not entail a highly invasive or intrusive approach. Zoo keepers and curators are typically 'animal lovers' who take great care of their livestock and place an extremely high value on welfare and conservation. However, this is not always well-communicated to members of the public. The partnership links between zoos and zoological research institutions may be regarded as particularly sensitive in some research contexts, e.g. where experimentation may be essential to better understand and cure a potentially lethal disease such as chytrid fungal infection in frogs. Research on human-animal communicable diseases (zoonoses) is another sensitive area, where individual zoos need to determine their policy.

Honest, sympathetic educational interpretation in the zoo can often help to promote a good understanding of the zoo policy and objectives; and proactively combat the misconceptions of some of the public and some staff. Signage and other interpretation is also essential to get across difficult scientific concepts such as population genetics and evolution through natural selection. At a very practical level, the ability to demonstrate educational output and benefit is a key feature of economic impact assessments (EIA's), possibly leading to European grants.

In summary, then, I strongly encourage all zoos and aquariums to:

Adopt the EAZA Research Mission

- adopt a more scientific approach
- participate in research and fund it
- provide research facilities, tools and staff
- produce and publish high quality research
- promote collaborative partnerships

and

Pursue the EAZA Research Vision

- make significant contributions to biological research, especially for biodiversity conservation and animal welfare
- use research results to improve decision-making for animal management and conservation and welfare projects
- engage in scientific education and training
- communicate at all levels the high value of research both to the staff and the general public.

Acknowledgements. I am grateful to Frances Jaques for helping me prepare this presentation, and to my colleagues Mark Pilgrim, Roger Wilkinson, Kevin Buley, Mike Jordan and Andrea Fidgett for stimulating discussions on the nature of science in zoos and aquariums.

The importance of zoo participation in global species conservation

Richard Perron

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Abstract: Zoos have a legal and moral responsibility to be active in conservation. Participation is possible through education & research, ex-situ and in-situ activities. It is important for zoos to publicise both their scientific knowledge and their mission statements in the interests of all zoos and conservation generally.

Key words: Conservation, directive, extinction, responsibility, marketing, education, research, ex-situ, insitu

I am about to make some statements which you may or may not agree with.

If you think I might mean you and your zoo, then I probably do.

YOU is what this talk is all about!

There are perhaps over 2,000 zoos, as defined by the European directive in EU/1999/22/EC of 29th March 1999, in Europe today.

Since there is extreme variation in size, quality and type of animal holding, not to mention individual local political attitudes and administrative systems, it is perhaps understandable that there is a multitude of conceptions about what is and how to go about conservation among zoos.

The dictionary defines conservation as:

- The protection of plants and animals, natural areas, and interesting and important structures and buildings, especially from the damaging effects of human activity
- Carefully using valuable natural substances that exist in limited amounts in order to make certain that they will be available for as long a time as possible

You will note that "recreate" does not occur and, strictly speaking, "re-introduction" is also not a conservation concept, although in certain circumstances it can be useful.

Projects like the European Bison and the Przewalski Horse may attract and deserve attention.

But they are not conservation efforts as such, anymore than recreating the Woolly Mammoth or the Sabre-toothed Tiger would be, and may divert scarce resources from more pressing causes.

Much of Europe and North America are areas with artificial wild animal populations, the result of centuries of uncontrolled human expansion and consequent wildlife decimation.

It is usually impractical to recreate or reinstall ancient habitats to support extinct animals which will, in any case, possibly adversely affect the currently resident species.

Why is conservation important now?

Depending on who you wish to believe, between 10% and 25% of the World's species are in danger of extinction within the next hundred years.

Parallels have been drawn to the great extinctions of geological times, but these underestimate the time dimension of this pending catastrophe.

What we are perhaps living through is a mass extinction spanning a few hundred years – a quick flash in geological time.

The main culprit is mankind, not a meteor from outer-space nor a gigantic volcanic eruption.

Directly, through destruction of habitat and hunting, and indirectly through pollution of various sorts, including the continuing contribution to global warming, humankind, *Homo sapiens*, is busy sawing off the very branch of life he is sitting on.

Why should zoos be concerned?

There are two reasons: one moral and one practical.

Moral responsibility

Zoos owe their existence to wild animals and have for centuries taken animals from the wild to put on show. Coincidently, the favourite zoo animals are among those most endangered.

This close relationship between zoos and wild animals brings a heavy moral responsibility with it to do something about saving endangered wildlife.

Their survival is your problem.

Practical reasons

The European Zoo Directive says that zoos must do something.

Although it may take a few years for all countries to implement this in legislation, it will become law in YOUR country.

It is to be regretted that often national zoo organisations seem unable to give leadership and are more concerned with their own image than with practical action to get all zoos involved in a joint effort for conservation.

The present directive, I assure you, is only the first one.

If zoos do not freely embrace conservation, they will be forced to do so by further legislation.

Zoos are not scientific jewels any more, but often public financial burdens which must justify their existence.

No conservation – no zoo!

Zoo directors can be likened to jugglers

They have many important aspects of their business to concentrate on and all at the same time.

These areas can be broken down into the following groups, each having more detailed sub-structures:

1. Care and husbandry of the zoo animals
2. The Zoo must be attractive and entertaining
3. It must be profitable or cover the costs

Additionally it should ideally:

4. Be educative
5. Be involved with ex-situ programmes
6. Be involved in in-situ projects

The first three are central factors which affect good, mediocre and bad zoos alike.

These deserve more attention, but time forbids me going into them.

The last three are conservation elements which should be implemented in all zoos, but are often ignored or are only superficially implemented for a variety of reasons.

Education

Education needs to be understood in a much wider sense than is often the case as it is the major way in which zoos can influence public opinion and directly encourage participation in conservation.

- Staff training – to create informed ambassadors and animal handlers who can correctly care for the animals, understand what they are doing and can communicate their knowledge to the public.
- Correct and sufficient signage is necessary. Bad or inadequate signage reflects on the competence of the zoo.
- Part of subliminal signage, the zoo should demonstrate that it practices what it preaches and have integrated environmental compatibility. That means cleanliness within the zoo, adequate waste disposal bins, recycling where possible, minimising the use of environmentally unfriendly materials and not wasting (water and energy!) generally.
- School parties – A particular effort should be made to attract the younger generation by offering special courses for schools. This is a conservation building block for future attitudes to wildlife and the environment.
- Children at play – Make it fun. Turn the playground into an animal kingdom or exotic environment. Integrate play with nature.
- Adult visitors – are a problem of apathy. Most people come to a zoo to enjoy themselves and not to learn things. However, events and games which combine family entertainment with a background of environmental facts can reinforce positive impressions gained in the zoo.

- Guided tours by zoo professionals – Don’t always let your visitors roam around alone. Offer short, free tours at weekends, run perhaps by the Friends of the Zoo and not just zoo staff.
- Research & publication.
- Marketing concept aimed at politicians.

Every zoo should have a marketing concept – know why you are there, what you are doing and where you are going.

Use the new World Zoo Conservation Strategy as your base.

Involve schools, churches, social groups and businesses in all your activities.

If possible, use your Friends of the Zoo to do the work.

Invite all political parties regularly to events at your zoo and keep them up-to-date with your plans and integrate them into your projects.

Encourage your national and regional association to produce a parallel document which you can use to support yours.

Ex-situ

Ex-situ conservation would seem to be the ideal level for zoos to become involved in conservation, the animals are often already there and fresh blood can usually be obtained free.

BUT, it should be remembered that captive breeding is of limited value when not coupled with in-situ support and the conscientious recording and publication of data.

Just being an EEP/ESB member and putting the logo on your enclosure is not a sufficient commitment. All too often this is an alibi for doing nothing.

Medium-term collection planning is essential and producing unwanted offspring defeats the object of a programme.

Zoos can often usefully serve conservation by maintaining single-sex groups as genetic reserves where current reproduction is adequate to maintain the population.

Some EEPs are refusing new members because they do not need more animals.

However, purely on safety and educational grounds, programme co-ordinators might consider widening the distribution of their species, even to the extent of encouraging zoos to take on new and discarding old species.

Space requirements for the larger mammals limit the maximum size of single holdings, but dispersion, possibly with financial assistance, could partly solve the problem. Too little attention is currently being given to endangered species which are not considered to be public attractions. Focusing on these “unattractive” species as part of your collection could be to your advantage.

With many endangered invertebrate, reptile, amphibian and avian species the participation of private individuals within programmes has proved invaluable.

Your visiting public probably harbours a wealth of untapped knowledge, assistance and avenues to funding. I have not said much about research, but it should be integrated into every zoo.

Research, in a small zoo which cannot afford a scientific officer or support doctoral students, can be seen as the diligent recording of animal behaviour in a collection.

There is a mass of scientific, useful information available in the daily contact with animals, their biological and sociological behaviour.

This information is only useful if it is published. Don't be shy – publish your experiences in print or in the internet.

In-situ is the crucial test

No amount of ex-situ work can compensate for the loss of a species' habitat. Protecting and preserving a species depends ultimately on the preservation and protection of its habitat. If you keep endangered species in your collection, you are failing them if you do not aid their in-situ conservation. In-situ does not have to be in far off lands, but can also mean doing conservation projects in your local area.

These projects do not have to focus on animals in your collection, but may use plant, invertebrate or fish flagship species. This shows potential financial supporters and your local politicians that you are serious about conservation.

Smaller zoos can join together to create viable projects for habitat protection both at home and further afield by forming an association with local interest groups on the spot. Many initiatives which have become success stories started out as a holiday journey to study zoo animals in the wild.

Larger zoos can supply technical as well as financial help to projects. Their leadership as an example to other zoos is not to be underestimated. Raise funds for projects you cannot join. Funding is a major problem for almost all conservation work, but a little goes a long way in the countries most in need of help. Your help in raising funds, and making sure it is channelled into a real project, is an easy way to participate directly. Everything you do in relation to in-situ conservation has a huge potential for positively advertising your zoo.

Any projects you participate in can be highlighted in your marketing concept and are an undeniable justification for your own continued existence.

The Reality Today

Very few zoos are actively engaged in conservation and usually the same zoos are always mentioned in connection with active projects. Zoos of all sizes can and should be doing more. If zoos fail to address the conservation challenge, the public will choose other entertainment sources and lawmakers will increasingly pass legislation enforcing your participation.

- Conservation needs YOU now
- Educate your visitors & politicians
- Do something positive for captive species
- Publish your experiences
- Help preserve **OUR** in-situ wildlife and habitat.

More data for your dollar. High quality research on a limited budget, the example of Paignton Zoo's research programme

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Abstract: The zoo environment provides a unique and valuable resource for scientific research not necessarily dependent on expensive equipment or specialist facilities. At Paignton Zoo Environmental Park, Devon, UK, we have created, with very limited financial resources, a relatively large and diverse Science Department, specialising in several areas of zoo research. Despite limited monetary support the Department continues to produce high quality, published research, collaborating with a range of research institutions and students. Research is carried out by permanent staff members and students from local universities and colleges and from further afield, ranging from BSc to PhD level. One of our most productive schemes in terms of research output is to offer year-long work placements or internships for students hoping to gain invaluable experience in the world of zoo research. Investigations are carried out on a range of topics including: reproduction, parasitology, behaviour and psychology, with studies in pure and applied areas often helping to solve husbandry problems and promote good animal welfare.

Key words: Research, animal behaviour, conservation, husbandry, animal welfare, environmental enrichment, animal training

Why carry out research in zoos?

Research is an important aspect of the work of modern zoos, as outlined in the UK Secretary of State's Standards of Modern Zoo Practice (2000), *"Zoos should be able to demonstrate that they encourage research. Research can be developed through forging links with Higher Education Institutions. Full details of such projects should be available on request." (SSSMZP, page 17, Research 7.8)*.

The zoo environment provides a unique opportunity for applied and pure research to be carried out on a range of subjects. Working directly with animal management and veterinary staff, priority research areas can be identified and project outcomes applied. Pure research aims to investigate and increase knowledge of various aspects of species biology. Zoo research also acts as an invaluable training tool for the researchers of the future, providing experience for both *ex-situ* and *in-situ* investigations and conservation.

Research within the zoo environment can provide valuable data and information on a wide range of aspects within animal management and husbandry with little financial input, providing evidence to help improve and promote captive animal husbandry and welfare. Areas investigated can benefit both animal and veterinary staff and essentially, the students, contributing towards academic qualifications ranging from undergraduate to PhD level.

Research in zoos is often limited due to finances money is required for two main purposes: researchers and costs of equipment/consumables.

Researchers

At Paignton Zoo, research projects are undertaken by permanent staff and visiting researchers, usually students. The science department comprises of two full-time and three part-time staff which is a significant but effective financial investment. The Head of Department Dr. Amy Plowman, specialises in nutrition and *in-situ* ecology, Research Associate Dr. Vicky Melfi, specialises in animal welfare and husbandry, and the three part-time research assistants are also studying part-time for their PhDs in the function of vocalisations in the black howler monkey, social mechanisms and conflict management in bachelor gorilla groups, and reproduction, genetic diversity and conservation of the meadow thistle. In addition to their part-time salaries, their PhD fees and research expenses are paid for by the Zoo. This is very cost effective not only in terms of their own research achieved, but also of other research supervised by them in the salaried half of their time.

At the zoo, we offer research projects to a range of both UK and international universities, for students studying for undergraduate and postgraduate final projects, up to PhD level. Students may also visit Paignton for short periods of time as part of a multi-institutional study or as a science department intern, hoping to gain experience in the world of zoo research. Since 1997, we have worked with students from over 30 UK universities and seven international universities and institutions. Over the past year (2004-2005) we have facilitated over 75 research projects across our three sites; Paignton Zoo, Living Coasts and Newquay Zoo, and our nature reserves; Slapton Ley, Clennon Gorge and Primley. We have also facilitated three overseas projects in Tanzania and Zimbabwe.

The science department also offers a year in industry placement to a small number of applicants. During this placement, the students study a year-long project, benefiting from data collected over all weather seasons and yearly cycles, often contributing to long-term studies. If well supervised this is therefore a very effective way of achieving good research. This academic year we have employed six one-year placement students, and next year will be increasing our intake to eight. The projects undertaken include woodland restoration, coalition and alliance formation in baboons and inter and intra-species interactions between wader birds. We do not offer a stipend to these students, so we make every effort to ensure they benefit greatly from the experience. They have opportunities to take a full part in a research environment, with the chance to be involved in other aspects of the zoo such as our enrichment group and educational presentations. Importantly they are strongly encouraged to attend and present at scientific conferences most notably at the British and Irish Federation of Zoos and Aquaria annual Zoo Research Symposium.

What research can be done for minimum cost?

To focus research within our department, three workgroups have been established: Behavioural Husbandry and Animal Welfare, focuses on the effect of captive environmental variables on animal biology, to measure and promote animal welfare in zoos; Behavioural Ecology and Cognition, focuses on behavioural ecology (social and developmental behaviour) and cognition; Conservation, Ecology and Environment, studies the ecology of threatened species and habitats, and habitat restoration (see de Vere, this volume, for further information on this group).

Within these groups, a wide range of research is carried out usually not requiring specialist equipment or financial input. These are often based on behavioural observation but other research such as nutrition, behaviour and psychology, with studies covering pure and applied aspects also do not require a specific budget. Research on studbook data can also be performed without financial input, requiring only access to the studbook itself and can often help the coordinator in determining guidelines and producing annual studbooks, (see Cocks, 1999). Three examples of projects completed at Paignton Zoo which did not require financial support are outlined below. These have all resulted in peer-reviewed publications and/or recognised by awards.

Can training zoo-housed primates compromise their conservation? A case study using Abyssinian Colobus monkeys (*Colobus guereza*)

Vicky. A. Melfi and Sian Thomas

The study tested the hypothesis that training of a non-human primate will affect its general behaviour pattern, outside of training. Ongoing oral problems in a group of Abyssinian Colobus monkeys (*Colobus guereza kikuyuensis*) were identified and on veterinary recommendation, a change in diet and regular oral examinations of the group requested. Oral examinations involved training the individuals to come to the front of their enclosure and present an open mouth to the trainer, without the requirement of leaving the enclosure or group.

Methods

Training

Eight Abyssinian Colobus monkeys (*Colobus guereza kikuyuensis*) (6:2) housed at Paignton Zoo, Devon were studied. In March 2003, the training regime began, the goal of which was to perform oral examinations on all group individuals whilst they remained in their enclosure. Positive reinforcement was implemented, using grapes as the reward (primary reinforcer) and a “clicker” as a bridge (secondary reinforcer). The individuals were trained to “station” at a specific area in the enclosure; whilst at the station, individuals were trained to hold their hands on the enclosure front mesh, and finally open their mouth and hold it open for examination.

Behavioural data collection

Behavioural data was collected during four conditions, each 12 days in duration; the first prior to training as a baseline and an observation period each month, for the three months post training. Instantaneous scan sampling was used to record state behaviours every 30 minutes from 0800-1600 on sampling days. Two 10- minute instantaneous focal follows were conducted for each individual on each day, sampling every 10 seconds. Proximity to other group members and colobus-initiated interactions with humans were also recorded during focal follows.

Results

Activity budgets

There was a significant difference between mean time spent performing behaviour between the four observation periods and the mean percentage of time spent resting increased from 53% to 64% and time spent feeding significantly decreased from 18% to 10%.

Time spent in proximity to other group individuals

The group spent approximately 25% of their day performing social behaviours. There was no significant difference in the time spent performing social behaviours between the four observation periods. During baseline observations, colobus were found to spend the majority of their time separated from other individuals by one arm's length or less. Distance between individuals changed significantly between observation periods with a decrease in the time spent separated from one another by two-five arm's lengths was found during the last observation period, when compared to the baseline data.

Colobus-human interactions

There was a significant difference in the number of colobus-human interactions during the observation periods, decreasing significantly post training.

Conclusion

The integration of training into the colobus daily regime was found to decrease colobus-initiated interactions with humans. The performance of social behaviours, proximity between individuals and activity budgets were not significantly affected by training. Overall, training was considered to be a positive addition to the colobus husbandry regime, supporting findings previously found by Prescott and Buchanan-Smith, 2003.

The study has been published in *Anthrozoös* (Melfi and Thomas, 2006) and the work achieved a BIAZA award in 2004 for 'Significant Advances in Husbandry and Animal Welfare for incorporation of positive reinforcement training into the husbandry of Abyssinian colobus monkeys'.

The function of notification in Hamadryas Baboons (*Papio cyanocephalus hamadryas*)

Orlaith Fraser and Amy. Plowman

Notification is a form of ritualised greeting behaviour unique to adult male Hamadryas baboons (*Papio cyanocephalus hamadryas*). Originally observed in the wild when harem leaders signalled the direction of travel to their followers on daily foraging marches, its true function is yet unknown. Notification involves the approach of an adult male baboon to another male and the presentation of his hindquarters, followed by a retreat. The eight hypothesised functions of notification in the study were as follows;

- Greeting – Notification would occur randomly between all adult males in the troop.
- Alliance – Particular pairs who interact frequently would notify to each other in approximately equal proportions and would not notify to others.
- Peace-keeping – Notification would occur between individuals of a similar rank who do not interact frequently in order to avoid conflict.
- Recruitment – Notification would occur between two males before they pair attack a third party.
- Submission – One way notification from lower ranking males to higher ranking males in the hierarchy would be observed.
- Appeasement – Threatening baboons would be notified but wouldn't notify in return. Appeasement would reduce the tension, so self-directed behaviours such as scratching and yawning which indicate high stress levels would be lower following notification.
- Reconciliation – Notification would occur after aggressive behaviour between individuals involved in the fight.
- Direction of travel hypothesis – Dominant males notify to followers before long distance movement.

Methods

The subjects of the study were the 8 adult males, all harem leaders of a troop of 60 captively bred baboons at Paignton Zoo, Devon. All data was collected from 0830 to 1030 and between 1130 and 1600 hours. Each of the eight adult males were observed individually, at random for 18 (nine on the rock and nine in the cage), 20 minute sessions. During observation sessions, interaction and self-directed behaviours were recorded continuously every two seconds. All notifications involving the focal baboon during a session were categorised into four main types and it was noted whether the focal baboon was the instigator or receiver.

Results and conclusion

Notification was found to play an important role in conflict management in its widest sense (Aureli & de Waal, 2000), through submission (increasing a dominant males' tolerance of a lower-ranking male), peacekeeping (reassuring potential opponents of non-agonistic objectives) and alliance formation (confirming a peaceful relationship with a similar-ranking individual).

This study has been accepted for publication; Fraser, O. and Plowman, A.B. (2006). Function of notification in hamadryas baboons (*Papio hamadryas*)? In: Melfi, V.A. and Pullen, P.K. (eds.). *The diversity of zoo primate research. International Journal of Primatology* (supplement).

Post-occupancy evaluation of a red river hog (*Potamochoerus porcus*) enclosure

Erik Dayrell and Kirsten Pullen

Red river hogs are generalist omnivores, feeding on roots, fruits, seeds, nuts and crops among other items. They are notorious for their extensive damage to crops in their native area throughout west and central sub-Sahara to Africa. In August 2002, three red river hogs; one adult male, one adult female and one juvenile female arrived at Paignton Zoo, Devon, UK. To assess their behaviour on introduction to their new enclosure, a post occupancy evaluation (POE) was carried out to document activity budgets and space use. Post occupancy evaluations are usually carried out to assess how people interact with their environment. In a captive animal setting, POE's can provide valuable information on changes in an animal's enclosure use over time and thus suggest ways in which refurbishing an enclosure may prolong its novelty and maintain its stimulation.

Methods

Data Collection

Observation periods occurred over 10 consecutive days, during late October 2002, late November 2002 and early January 2003. Instantaneous scan sampling every minute during a 30 minute session was used to record behavioural expression. Location within the enclosure for all individuals was recorded using a pre-determined enclosure map in which the enclosure was split into different resources.

Following initial data analysis, it was decided to incorporate enrichment into the daily husbandry routine in the form of scatter feeding, in an attempt to bring back the behaviour and enclosure use of the hogs before they became habituated. Scatter feeding was incorporated into the husbandry routine twice a day and a fourth data collection period was carried out.

Results

Before enrichment introduction

During the first three sampling periods, the hogs foraged most when there was a large amount of foliage (when they were first put in the enclosure). When foliage cover decreased, the hogs spent more of their spent rooting in the soil, finally switching back to foraging as new vegetation started to grow. There was a significant decrease of 37% in space use over the first 2.5 months of data collection. This result was possibly due to a decrease in vegetation, decreased novelty of the enclosure and repetitive feeding in one location of the enclosure.

After enrichment introduction

Results showed that implementing scatter feeding twice a day was found to significantly promote foraging, time spent immobile reduced and the behavioural budget and enclosure use returned back to that on initial introduction.

Conclusion

The post occupancy evaluation carried out in this study allowed us to evaluate the effectiveness of their enclosure and target areas needing improvement, particularly where enrichment was involved. The introduction of scatter feeding was successful in achieving our aim of bringing back the behaviour and enclosure use of the hogs, to that of when they were first introduced. By providing their diet in different areas of their enclosure, the hogs were encouraged to forage and root for their food, behaviours which are commonly seen in the wild.

This project was awarded a BIAZA Commendation in 2005 for Significant Advances in Husbandry and Animal Welfare for a post-occupancy evaluation of a red river hog enclosure and has been published as an article in Shape of Enrichment Vol 15 (1), 2006.

How can you achieve research?

Employing permanent staff with research expertise allows us to focus research on the needs of the zoo, develop our own research project list and supervise visiting students to a high standard, thus ensuring that all research is worthwhile and potentially publishable. However, even without specialist staff, student research within the zoo can be facilitated provided they have adequate academic support from their institution.

Establishing links with local universities will help to provide both student and academic advice on project design, analysis and publication submissions. Often university supervisors will provide project ideas and work alongside the zoo to develop long-term research projects and establish research areas. From building up links with local universities, zoos may be eligible to apply for external research funding and if a research assistant is appointed, the university may provide financial support by means of a staff financial stipend. We have had this arrangement in the past, although care needs to be taken to ensure that responsibilities and management lines are clear.

From our links with the University of Plymouth, Devon, Paignton Zoo science department, alongside the university have developed a post-graduate course, an MSc Zoo Conservation Biology, which is taught both by science department staff (now Associate lecturers) and university lecturers. The course covers modules including animal conservation, animal health and welfare and introduction to zoo organisation. Science department staff also teach on the University of Exeter's MSc Animal Behaviour course and present at a range of universities in the UK, as guest speakers. As well as being important in developing academic links, these have provided a source of income to fund research.

Facilitating research between students and keepers is a beneficial way of starting to manage zoo research. Appointing one member of staff as a point of contact for students will help initiate links and facilitate research, independent of financial support.

Paignton Zoo has one of the most active research programmes in the British zoo community and plays an important role in the Research Group of BIAZA, which works to promote zoo research, facilitate multi-zoo research and produce guidelines on research sampling and planning projects in behaviour. The BIAZA Research group produces a quarterly review, entitled Research News, as a source of ideas and detailing similar research which is received by all BIAZA members and can help to instigate ideas and collaborations between zoological institutions.

The zoo environment presents a unique and valuable resource for research, often requiring little or no specialist facilities or financial input. Paignton Zoo has developed a science department which with limited monetary support, produces a high standard of work, collaborating with a range of institutions and students, investigating a range of topics, covering both pure and applied aspects, often helping to improve animal husbandry, welfare and conservation.

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Optimalising the role of animal rescue centres by researching the source of the problem

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Abstract: This paper discusses several ways in which rescue centres worldwide are expanding their role by researching problems related to the animals they receive. They are key witnesses to the serious welfare implications for wild animals that fall victim to, for instance, the animal trade and entertainment industry. The work of AAP, Sanctuary for Exotic Animals in the Netherlands will be highlighted as a case in point. Many behavioural studies are done in this centre on the resocialisation of primates and other (exotic) mammals. Information about the effects on the animals is recorded and statistics are kept on the requests for intake from all over Europe. An in-situ research project has been running since 2003 to investigate the illegal trade route of the Barbary macaque *(Macaca sylvanus)* from North Africa into Europe, and the consequences for the wild population. Monitoring exactly what is needed, and why, is fundamental to start solving the issue at the source. By professionalising and making use of their observations to good effect, those involved in the rescue and rehabilitation of displaced animals can effectively alert the (international) public and relevant authorities.

Key words: role of rescue centres, rehabilitation of wild animals, Barbary macaque, animal trade, animal welfare, AAP Sanctuary for Exotic Animals

Introduction – Beyond the call of immediate rescue

Wild animal rescue centres and sanctuaries[1] can be found in great numbers all over the world. Many have evolved from people rescuing the odd individual into centres that accommodate hundreds of displaced animals today. The causes underlying the displacement of primates and other wild animals range from bush meat harvesting,

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[1] In this article no distinction is made between rescue centres, sanctuaries and rehabilitation centres (i.e. whether they offer temporary, permanent places and/or release animals back into the wild). The fact they receive displaced animals is relevant to the points discussed.

live (pet) trade and habitat destruction in Africa, Asia and South America (Camperio Ciani 2005; Cheyne 2004; Goossens 2005; Leiman 1996), to the housing crisis of ex-laboratory primates in the US (Noon 1999) and the entertainment industry in Europe (Margodt 2000). Most rescue centres will attest to the fact that the more known they become by the public and the authorities, the more animals arrive at their doorstep (e.g. Noon 1999; Hanson-Alp 2001; Schmitz 2003; Farmer 2002a). Although in principle worth encouraging, intake capacity often cannot meet the demand. Turning down a neglected animal, or not being able to facilitate a confiscation as a result, seems to defeat the purpose of their existence. Therefore, apart from remedying the consequences, there is an increasing awareness amongst rescue centre staff that working on prevention of the problems should be included in their daily activities as well (Hanson-Alp 2001; Jane Goodall Institute 2003; Cox 2000).

The drive to start tackling the wider issues has led to a notable professionalisation of many rescue centres worldwide. Actively seeking publicity, obtaining official recognition and confronting the public and authorities to stimulate legislation and its enforcement, are means that have already helped to achieve this. By employing experienced and educated staff, and attracting international scientists, many sanctuaries are increasingly engaging in important research activities (Schmitz 2003; Farmer 2006; Cox 2000; PASA 2005; Goossens 2005; van Lavieren 2004). International sanctuary associations such as PASA (Pan African Sanctuary Alliance) have been created with the aim to improve standards of care and management and develop strongholds in tackling issues more effectively (Farmer 2002a; IFAW and BCTF 2003).

The discussion will now turn to the work of AAP, a European rescue centre in the Netherlands. Since its establishment in the seventies, AAP has made great progress in extending its activities from sheltering local rescue animals, to becoming an important player on the international field of animal welfare. As a professional rescue centre AAP continues to improve its husbandry techniques, and a lot is invested in the rehabilitation system. This has allowed AAP to accumulate expertise, and to demonstrate a high success rate of recovery and resocialisation of problem animals. Secondly, it aims to solve the issues causing the influx of displaced animals. Keeping track of where the animals come from, and why, helps to provide an accurate picture of exactly how far-reaching the problem in Europe is. Current efforts to tackle some problem sources are focused on lobbying to prohibit certain exotic species as pets in the Netherlands; advocating a ban on the use of wild animals in circuses; and, as will be discussed later on, researching the illegal trade of Barbary macaques in Europe.

Behavioural and physical rehabilitation at AAP

AAP specialises in primates and other small mammals exotic to Europe, and houses more than 350 animals today. First of all, AAP provides first-line rescue, shelter and rehabilitation[2] for displaced individuals. Many are either confiscated in accordance with animal welfare or conservation legislation, or voluntarily offered by the public. Common sources are (illegal) trade and private pet-keeping, circuses, closed down

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[2] In this article 'rehabilitation' is used to describe remedial treatment, physical and behavioural, not including the release of animals (back) into the wild.

zoos and surplus stock from biomedical laboratories. Apart from showing signs of inadequate medical and nutritional care, many (often orphaned) animals that arrive at AAP have little social experience and regularly display abnormal behaviour.

The intake of an animal is followed by a minimum quarantine period of six weeks. At this stage, animals are tested for viruses, bacteria and parasites, and receive the necessary vaccinations. Additionally, a first assessment is made of the behaviour of the animals, slowly weaning them off human contact. During their further rehabilitation, an elaborate plan is set up covering, for example, introduction into social groups, diet and enrichment. Trained keepers methodically perform behavioural observations under the supervision of ethologists. Before, during and after integration into groups, observations are recorded for the purpose of analysing the progress of the animals. These behavioural analyses demonstrate that even mammals considered largely solitary in the wild, such as raccoons and skunks, can benefit from 'social' housing. Once a group is stable, permanent placement is sought outside the centre. This occurs usually to zoological parks worldwide, whereby the animals remain in ownership of AAP. Subsequently, new rescued animals on the waiting list for intake are brought in to utilise the vacated space. This system of intake and outplacement is preferred in order to maximise the turnover of animals, and further improve the quality of life of the rehabilitated individuals. Internal research activities are frequently carried out, such as studying the measuring of welfare of ex-laboratory chimpanzees, resocialisation methods, behavioural enrichment to tackle stereotypies, *Baylisascaris procyonis* in raccoons and the effects of birth control on social behaviour.

Success rates for resocialising primates

Despite receiving many adult primates, which are usually difficult to introduce into existing social groups (Cox 2000), the percentage of solitary animals at AAP has been reduced to below 5% today. In the period between January 2001 and April 2006, AAP took in a total number of 139 primates. 6 had to be euthanised on veterinary grounds, 6 were relocated and 5 had to be returned to their previous owners following confiscations. For 63 individuals it was assumed they had little to no social experience with conspecifics; 54 of them were successfully resocialised. This shows a success rate of 86 % over 5 years. This is a conservative figure, as some animals died in the resocialisation phase (of causes presumed to be

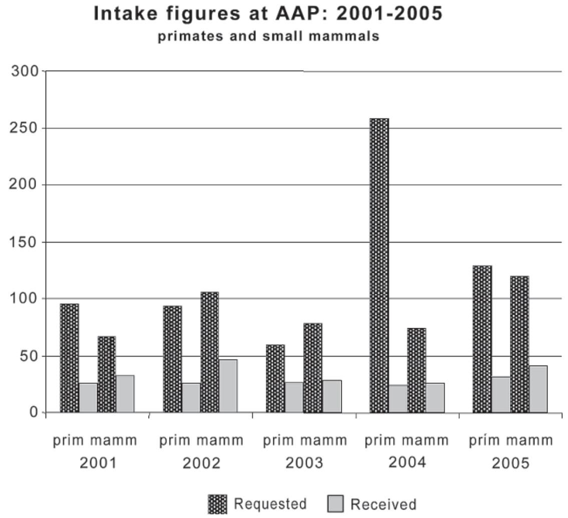

Fig. 1. Number of primates, including chimpanzees, and other small mammals from all over Europe for which shelter was requested at AAP, compared to what AAP was able to accommodate

unrelated to their resocialisation) and some animals were still in this phase on July 1st 2006. Other research has confirmed the positive results and feasibility of resocialising previously solitary primates. It can strongly decrease the abnormal behaviours they have developed during the often unnatural circumstances which they have had to endure (e.g. Kessel 2001). Rescue centres, by virtue of their drive and their professional goals, provide an ideal opportunity to fulfill this task with regard to the rehabilitation of traumatised animals (Cox 2000).

Keeping records to quantify the problems

An accurate record-keeping system for institutes receiving displaced animals allows a quantification of the particular issues at hand. Since 2001, AAP has meticulously registered every single intake, as well as every request for intake. Details are documented concerning the species, gender, age, the origin and, who is requesting shelter, the availability of the animal (e.g. legal documents for relocation). As much information as possible is gathered about the behavioural and physical state of the animal. Obtaining comprehensive data can help to develop relevant policy decisions and long term strategies, as apposed to solely reacting on an ad-hoc and ad-lib basis (see also: Farmer 2002; Cuarón 2005; Cox 2000).

Perpetual lack of shelter in Europe

AAP’s regular communication with other European rescue centres and animal welfare organisations shows that most find great difficulty to respond to the demand for shelter (see also: Schmitz 2003; van Lavieren 2004). Their information furthermore reveals that what is registered at AAP (see Fig. 1) represents merely a fraction of the true number of animals requiring shelter in Europe. Taking the capacity into account and respecting a particular level of quality, AAP can only satisfy roughly a third of the requests for shelter (see figure 1). These facts further confirm that there is a significant placement problem in Europe. Many animals that cannot be placed immediately either disappear (e.g. from private individuals), or are euthanised by the confiscating authorities. This is one of the recommendations by IUCN for disposing of confiscated live animals (IUCN 2002). AAP will always encourage people to place an official request for intake, even if the animals cannot be taken immediately. This is imperative in order to get an accurate idea of the scale of the problem. As a result of the lack of shelter, authorities are discouraged and are sometimes unable to enforce legislation (Schmitz 2003; van Lavieren 2004; personal observation).

The effects on wild populations: researching the illegal trade of Barbary macaques

Any animal arriving at a sanctuary usually serves as an indicator of a larger threat, and quite commonly one concerning the population of that species in the wild (Jane Goodall Institute 2003; IFAW and BCTF 2003). One of the dominating trends AAP has detected in the past five years has been the alarming number of Barbary macaques (*Macaca sylvanus)* requiring shelter. They are smuggled into Europe, mostly from

Morocco and Algeria, to keep as pets or fighting monkeys (van Lavieren 2004; Henley 2000). Since it was far beyond AAP's capacity to accommodate all these severely neglected primates, a long-term research project was initiated in 2003 to investigate the cause and scope of the problem. Trade routes were identified and surveys done with various zoological parks and sanctuaries in Europe that are regularly offered wild-caught Barbary macaques. A conservative estimate of at least 300 animals is thought to enter Europe annually (van Lavieren 2004). Already considered threatened as a result of logging, overgrazing and drought (Taub 1977; Fa 1984; Camperio Ciani 2005, 1995), current harvesting rates for the pet trade in Europe predict a bleak near future for this species in the wild (van Lavieren 2004). Results of the research will be used to increase international awareness, encourage protection of Barbary macaque habitat, target public education about the consequences of smuggling these animals and stimulate law enforcement at the European borders. AAP is one of the few institutions in Europe still regularly taking in Barbary macaques. Currently it houses 37 Barbary macaques, and in the past 2,5 years over a hundred have been placed on the waiting list for shelter.

Aiming to raise standards

Although the educational value of keeping a confiscated animal is recognised (IUCN 2002; Leiman 1996), it must not seriously compromise the welfare of the individual animal (Schmitz 2003; Cheyne 2004; IFAW and BCTF 2003). A placement solution provides an essential role in wildlife protection through facilitating law enforcement, but this solution is not complete without offering adequate care and housing (IUCN 2002; Cox 2000; IFAW and BCTF, 2003). There have been several cases of animals arriving at AAP that have been confiscated by the authorities from facilities claiming to be sanctuaries. Their standards were judged to be in breach of animal welfare laws. In the same way that some zoos complain that the bad reputation of others in their 'business' affects their own, sanctuaries too can suffer a similar fate. Showing and explaining the work performed to the outside community can help to prevent, or recover, a negative reputation. It is furthermore a stepping stone to achieve the needed support (Leiman 1996; Cox 2000; Hanson-Alp 2001). Rescue centres should use this support to raise standards, and obtain (official) recognition.

Conclusion: a need for professional rescue centres

Many rescue centres have already started to optimalise their role by expanding their activities. These activities include lobbying for the banning of wild animals as pets, protecting their natural habitat and researching the impact on wild populations.

Sufficient placement options for displaced wild animals, especially those that offer good husbandry standards and housing, are severely lacking. AAP's long-running experience and cooperation with other international organisations shows that in Europe this lack of shelter is evident as well. Keeping precise records of the displaced animals helps to determine how effectively to tackle the underlying reasons. For example, the notable increase of Barbary macaques needing shelter led AAP to start researching the extent and consequences of the illegal trade in Europe. Apart from the serious welfare implications, results suggest that the species in their natural habitat is becoming highly endangered.

Research on behaviour and rehabilitation techniques in sanctuaries, as is being carried out at AAP, shows that disturbed animals can, in the majority of cases, recover to live healthy, more natural lives. Rescue centers should aim to develop into professional organizations, offering a high standard of care and investigating the problems in order to propose effective solutions.

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Houston Zoo and Rice University: Institutional Symbiosis

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Abstarct: We report on a novel university–zoo partnership – the Houston Zoo and Rice University Consortium in Conservation Biology – established in January 2004. The consortium connects students and keepers; the former are given the opportunity to work with a diverse number of animal species, and the latter can employ the results of the research in exhibit management. Moreover, this close cooperation provides the researchers with additional background information from the zookeepers and ensures the meeting of the American Zoo Association standards. My presentation gives an overview on the workings of such close collaboration, and provides examples of the fascinating and valuable research conducted by the students under the guidance of zoo curators and staff.

Key words: environmental enrichment, animal behavior, cooperation, zookeepers, students

Zoological gardens frequently draw the attention of university students with their vast research opportunities. Yet independent zoo investigations are often unexpectedly challenging. Without the help of a keeper it is not easy to obtain basic background information such as sex, age or number of animals in an exhibit, not to mention their origin or past illnesses. Observations are often problematic, especially since general public does not usually have access to the entirety of the enclosure. Furthermore, certain behaviors that are typical only for particular individuals in a species can lead to misinterpretations or invalid generalizations. All of the above results in erroneous or incomplete information, and decreases the credibility of the research.

On the other hand, zookeepers see brilliant opportunities for research projects every day. These are predominantly aimed at improving the lives of animals in captivity, and deal with issues such as environmental enrichment or exhibit management. Still, the keepers simply do not have the time for intense daily surveillance and additional work. The solution comes with a close cooperation between two institutions, a collaboration aimed at producing research that is valid and useful for both parties involved.

Houston Zoo and Rice University Consortium in Conservation Biology was formed in January 2004, by Co-Directors Stan Mays, the Curator of the Houston Zoo's Reptile Department, and Dr. Lisa Meffert, an assistant professor of Ecology and Evolutionary Biology at Rice University, who had already been collaborating on research projects for many years. Dr. Meffert stated "It's only fair that the zoo gets credit for helping with Rice research. At the same time, we'd like to reciprocate to the zoo staff and give them any benefits that Rice may have that could help with their work." (pers. comm.) The Consortium in Conservation Biology (CCB) was formed and designed to merge the academic and applied interests of the two institutions for advancing theory and methods in the preservation of biodiversity.

In order to establish a set of guidelines for the researchers, the consortium formed the Institutional Investigative Studies Committee (IISC.) This committee is comprised of animal programs director Sharon Joseph, conservation specialist Bill Konstant, Dr. Joe Flanagan and Dr. Lauren Howard from the vet staff, lawyer Gale Johnson, zookeeper Stephanie Nageotte, as well as Stan Mays and Dr. Lisa Meffert. The guidelines of the committee mimic an Institutional Animal Care and Use Committee (IACUC). However studies by the Rice students were to be non-invasive.

The IISC designed a proposal that was to be presented by students for approval before the commencement of their projects. This proposal was intended to maintain continuity with the Rice students, follow keeper guidelines, and to integrate the background knowledge provided by the zoo into the future investigation. It was also designed to keep the animal's welfare at the forefront. The proposal headings contained the title, names of principal investigators, background and objectives, and preliminary data. The format also included sections on methods, statement of problem, a timetable for proposed project, animal care considerations, analytical considerations, and the significance of proposed research. In addition, the students submitted progress reports throughout the course of the project, reporting on conducted measurements, obtained results and difficulties encountered.

Initially, the students and keepers met during two sessions, in which the keepers presented their ideas about the research that could be done on their animals, primarily involving behavioral observations. Students exchanged contact information with the keeper whose project held the most interest, and thus initiated the collaboration on a particular investigation.

Under the zookeeper's tutelage, pending approval by the committee and appropriate curator personnel, the Rice students would be given free reign to do their research. Success could already be seen within the first year of the Consortium's existence. Conducted projects encompassed a variety of topics, such as the visitors' knowledge of endangered species, spectacled bear pacing in the moat, free range vs. captive golden lion tamarin family group study, Attwater prairie chicken research etc.

One of the more prominent studies concerned an okapi that was overgrooming itself to the point of lesions. Two Rice students, Diana Cox and Cydney Peterson designed a puzzle feeder to keep the animal occupied; this form of enrichment engaged the okapi sufficiently enough to put an end to the overgrooming problem. The project involved a number of areas of the zoo, including maintenance staff such as Paul Taylor, who constructed the feeder. Apart from dealing with specific challenges, students also contributed to a deeper understanding and knowledge of the zoo's animal collection.

Conducting research on zoo grounds opens a wide range of perspectives for students. The Consortium offers a backstage pass to zoo exhibits, enabling the acquisition of hands-on knowledge of species housing, management, conservation etc. Furthermore, the enthusiasm and support of the keepers immensely facilitate the investigations.

In return, zoo employees benefit by having visiting scholar status, which entails use of the library and class auditing. Through the consortium, both institutions will also be included on any research manuscripts produced by the collaboration between the zoo and the university. Both Rice University and the Houston Zoo have good reputations, and this formal collaboration will bring together the best of both the academic and practical worlds.

Acting locally: Paignton Zoo's conservation research programme for native species and habitats

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Abstract: The conservation of native species and habitats is an effective way for zoos to meet conservation targets. The Whitley Wildlife Conservation Trust, parent organisation for Paignton Zoo Environmental Park owns three nature reserves whose mission is to protect biodiversity. Within these reserves and other local habitats we conduct research to: monitor the species present, evaluate habitat management and restoration and further scientific knowledge of key species and habitats. We maintain a list of potential projects that are carried out by students from BSc to PhD level. The following case studies illustrate the range of our research.

1. Monitoring: Creation of a database for native species.
2. Evaluation of habitat management: The effect of coppicing on small mammals, butterflies, Carabid beetles and plants within Clennnon Gorge nature reserve.
3. Investigating habitat restoration: Use of yellow rattle in the restoration of a species rich hay meadow in Primley Park
4. Increase scientific knowledge of key species and habitats: The effect of population size and habitat quality on levels of genetic diversity in meadow thistle.

Key words: Local conservation, native species and habitats, coppicing, *Rhinanthus minor*, habitat restoration, *Cirsium dissectum*, population size

Introduction

The World Zoo and Aquarium Conservation Strategy (WAZA 2005) suggests that "zoos and aquariums enhance their sites with a view to providing habitats for threatened native species". Zoos often contain a mosaic of habitat types including grassland, woodland, lakes and linear features such as hedgerows and streams. The location of many zoos in urban areas means that they provide a green oasis in a sea of development. The conservation of native species and habitats is thus an effective way for zoos to meet conservation targets. To enhance zoo sites for wildlife we need to protect the habitat we have within our grounds and manage it with wildlife in mind. In many European countries so many habitats have been lost that is also often necessary to recreate areas of rare habitat such as species rich grasslands and ponds.

To protect habitats that are important for wildlife we need to have an understanding of the species and habitats found within our zoo sites, we also need to evaluate any management changes that take place to ensure they are meeting our objectives. This means that we need to carry out surveys and regular monitoring. We can also extend this and become involved with furthering scientific knowledge on key species and habitats both in and outside of the zoo grounds. Working with other local conservation organisations (e.g. the Wildlife Trusts within the UK) can help identify research priorities. We can also contribute to research within national conservation frameworks; in the UK this can be achieved by working within the Biodiversity Action Plans (BAPS). There are 391 plans for species, 45 for habitats and 162 Local BAPS (www.ukbap.org.uk). These plans are the UK government's response to the Convention on Biological Diversity (CBD) signed in 1992.

The Whitley Wildlife Conservation Trust (WWCT), parent organisation for Paignton Zoo Environmental Park owns three nature reserves whose mission is to protect biodiversity. Within these reserves and other local habitats we conduct research to: monitor the species present, evaluate habitat management and restoration and further scientific knowledge of key species and habitats. We maintain a list of potential projects that are carried out by students from BSc to PhD level. Each year we offer two industrial year placement projects in ecology, were students spend the year carrying out their own research project and helping with practical habitat management. We also offer 4-5 BSc honours projects and 2-3 MSc projects covering ecological and conservation based research. The following case studies illustrate the range of our research on native species and habitats.

Monitoring

Creation of a database for native species

Monitoring of the native species present within Paignton Zoo allows us to: assess the extent of biodiversity, monitor changes and consider the impact of zoo developments on native species. We can produce species lists and distribution maps for management plans and send records to our local biodiversity records centre.

Evaluation of habitat management

The effect of coppicing on small mammals, butterflies, Carabid beetles and plants within Clennnon Gorge nature reserve.

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Clennon Gorge is a 24ha nature reserve, partially within the grounds of Paignton Zoo, which contains a variety of important habitat types including calcareous grassland, ancient woodland, a pond and a stream. In the past the woodland had been coppiced to provide fuel for lime kilns but this practice stopped over 100 years ago. Coppicing is a traditional land management practice that provides a useful source of timber and also a mosaic of habitat types that are important for many native species (Fuller and Warren 1993).

In 1997 coppicing was reinstated to a small area of woodland within Clennon Gorge with the objective of increasing the diversity of plant and animal species. Between 1997 and 2003, 740 m^2 coppice plots were established. In 2003-4 a monitoring project was set up to investigate whether the coppicing had been effective in increasing diversity. This project's aim was to compare the flora and fauna of different aged coppice plots by comparing butterflies, Carabid beetles (Coleoptera, Carabidae), small mammals and ground flora.

Methods

Eight coppice plots were compared varying from 6 years since cutting to a plot cut the year of the study and a relic coppice plot that had not been cut for at least 100 years. The ground flora was sampled by identifying the species present in 102 m^2 quadrats per plot. Butterflies were sampled using a transect, walked once a week from March to July. Carabid beetles were caught using 9 pitfall traps per plot and small mammals were surveyed using 8 Longworth traps per plot.

Results

Table 1 shows correlation co-efficients between the number of years since a plot was cut and the species richness, abundance and diversity for each of the taxa studied.

Table 1. Correlation co-efficients (Spearman's rho) between the number of years since a coppice plot was cut and the species richness, abundance and diversity (Shannon's diversity index) for butteflies, Carabid beetles, small mammals and ground flora. * represents a p-value of less than 0.05 and (*) a p-value of less than 0.1

N = 8 Spearman's rho	Species richness	Species abundance	Shannon's Diversity index (H)
Butterflies	-0.589	-0.407	-0.638(*)
Carabid beetles	-0.309	-0.762*	-0.096
Small mammals	0.701(*)	0.479	0.527
Ground flora	-0.731*	NA	NA

Conclusions

The different aged coppice stands show differences in species richness, abundance and diversity for many of the groups studied. The number of ground flora species and abundance of Carabid beetles declines significantly as the coppice ages; butterfly diversity also decreases. Small mammals show a contrary trend with more small mammals found in older coppice. These results show that the reinstatement of coppicing has indeed created a mosaic of habitats for different species. The creation of gaps in the most recently coppiced plots favours butterflies, ground flora and Carabid beetles whilst the older coppice provides an important habitat for small mammals.

Investigating habitat restoration

Use of yellow rattle in the restoration of a species rich hay meadow in Primley Park

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Primley Park is a nature reserve and public open space, owned by the WWCT and located close to the grounds of Paignton Zoo. The reserve contains a 9 ha woodland and a 3 ha meadow that was formerly used as horse pasture and has been fertilised, creating a species poor sward dominated by a small number of coarse grass species. Since WWCT took over management of the meadow the objective has been to increase the plant species diversity. All fertiliser additions have stopped and each year the meadow is cut and the arisings removed, with the aim that this will gradually reduce the fertility of the site, providing conditions more suitable to a range of wildflower species. Primley meadow is however in the middle of a highly urbanised area so the possibility of wildflower species colonising naturally is very small. With this problem in mind an experiment has been set up to investigate the best way of increasing plant species diversity in Primley meadow. This investigates the use of adding wildflower seeds to the site and also investigates the use of yellow rattle (*Rhinanthus minor*). Yellow rattle is a hemi-parasitic plant that gains nutrients from coarse grasses, thus reducing their vigour (Bardgett *et al* 2006). Pywell *et al* (2004) have shown that growing yellow rattle can improve the establishment chances of other wildflowers. The current project investigates the use of yellow rattle, a range of wildflower species and different management techniques in increasing plant species richness in Primley meadow.

Methods

A site survey was carried out to determine the National Vegetation Community (Rodwell 1992) of the site. This was used to establish a list of potential wildflowers that could be established that would be consistent with the plant community already present. It was decided to add a small number of species that did not have any complicated dormancy or germination requirements, were suitable for sites with relatively high productivity, were attractive to a variety of insect species and were aesthetically pleasing to the public. Species chosen were yarrow (*Achillea millefolium*), black knapweed (*Centaurea nigra*), ox-eye daisy (*Leucanthemum vulgare*), selfheal (*Prunella vulgaris*), field scabious (*Knautia arvensis*) and yellow rattle (*Rhinanthus minor*). It was attempted to collect seed locally to ensure that it was of local provenance but where this was not possible a seed merchant was used that could guarantee that seed was from the UK. Two site preparation techniques were used to investigate which allowed greater seedling establishment. The techniques were cutting the grass to a sward height of approximately 1cm (short cut) or to rotovate the soil to create greater establishment gaps.

602 m^2 permanent plots were marked in the meadow with a separation of 2 m between each quadrat. The plots were arranged into 5 replicate blocks with 12 treatments (Table 2). Plots are monitored weekly to measure germination of the added species and each month all of the species present within the plots are recorded and their percentage cover determined. The percentage cover of bare ground (important for establishment gaps) is also measured.

Table 2. A list of the experimental treatments applied to Primley meadow

Experimental Treatments
1. Short cut and control
2. Rotovation and control
3. Short cut and wild flower seed mix sown in September 2005
4. Rotovation and wild flower seed mix sown in September 2005
5. Short cut and wild flower seed mix sown in September 2006
6. Rotovation and wild flower seed mix sown in September 2006
7. Short cut and yellow rattle sown in September 2005
8. Rotovation and yellow rattle sown in September 2005
9. Short cut and yellow rattle and wild flower seed mix sown in September 2005
10. Rotovation and yellow rattle and wild flower seed mix sown in September 2005
11. Short cut and yellow rattle sown in 2005. Wild flower seed mix sown in September 2006
12. Rotovation and yellow rattle sown in 2005. Wild flower seed mix sown in September 2006

Initial Results

At this stage eight of the treatments have been completed; the remaining treatments will take place in September 2006 and the experiment will be monitored over a number of years. In April 2006 seedlings of yellow rattle were observed in the plots were it was seeded, showing that the species is able to germinate successfully.

Where the short cut was applied the grass height was reduced to approximately 1cm and the initial mean bare soil percentage cover was 18%. The rotovation treatment turned the top layer (3 cm) of the soil and the initial mean bare soil percentage cover was 41%. Bare ground remained for longer with the rotovation treatment, with some of the plots consisting of 20% bare soil even after 6 months. It appears therefore that rotovation provides good establishment gaps and this may improve the survival rate of the added wildflowers.

Increase scientific knowledge of key species and habitats

The effect of population size and habitat quality on levels of genetic diversity in meadow thistle.

Natasha de Vere

Meadow thistle (*Cirsium dissectum*) is a key species of purple moor grass and rush pasture, a habitat that is subject to a UK Biodiversity Action Plan (UK Biodiversity Steering Group 1995). This habitat is of high conservation value due to its high species diversity and the large number of rare species that it supports. It is highly susceptible to agricultural modification and reclamation and many sites have been lost, reduced in size and become increasingly isolated. Within the UK, the county of Devon (where Paignton Zoo is located) is a stronghold for this habitat but even here only 8% of that present in 1900 remains (UK Biodiversity Steering Group 1995). In order to protect the habitat we need to understand the ecology of the species it is composed of.

A number of studies have shown that reductions in population size can have negative impacts on plants and animals, through loss of genetic variation, inbreeding depression and allee effects (see Oostermeijer, Luijten and den Nijs 2003 for a review). As populations become smaller the quality of the habitat also changes and this may also have an effect on genetic variation, but little research has been carried out in this area.

The aim of this project is to investigate the effects of population size and habitat quality on levels of genetic diversity in meadow thistle. It is hoped that this research will help to provide some suggestions for current management of purple moor grass and rush pasture sites as well as contributing to our knowledge of the effect of habitat destruction and modification on plant species.

Methods

22 populations of meadow thistle were sampled, distributed throughout England, Wales and Ireland. The populations represented a range of population sizes and habitats. For each population the following data was collected.

i) *Population area*: A global positioning system (Garmin eTrex) was used to provide the latitude, longitude and altitude of a number of plants on the periphery of the population. GPS Area (Read 2005) was then used to connect the points together and measure the area covered.

ii) *Genetic diversity*: 7 microsatellite loci developed by Jump *et al* (2002) for *C. acaule* were re-optimised for use in *C. dissectum.* 35 leaf samples per population were genotyped. Allelic richness (A) and the proportion of polymorphic loci (P99) were determined using FSTAT (Goudet 2001).

iii) *Habitat quality*: soil samples were taken and levels of organic matter, phosphorus, total nitrogen, calcium, potassium and pH measured. In order to estimate site management the mean vegetation height and percentage cover of bare ground was determined in 30 1 m^2 quadrats.

Results

Population area and habitat effect levels of genetic diversity in meadow thistle. Figure 1 shows that the proportion of polymorphic loci increases with population area (F-ratio = 9.444, R = 0.566, p-value = 0.006).

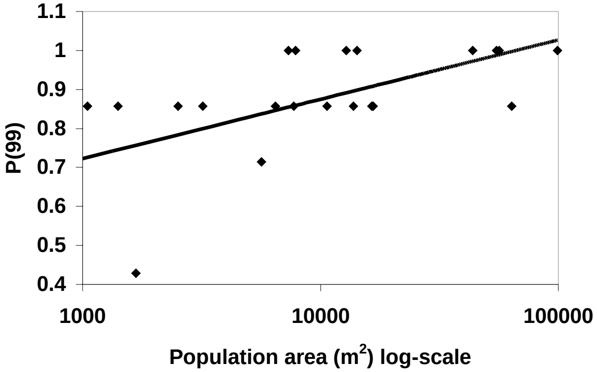

Fig. 1. The relationship between population area (m^2) and the proportion of polymorphic loci (P99) for 22 populations of *Cirsium dissectum*

Figure 2 illustrates an increase in allelic richness as the amount of bare ground increases (F-ratio = 12.314, R = 0.617, p-value = 0.002).

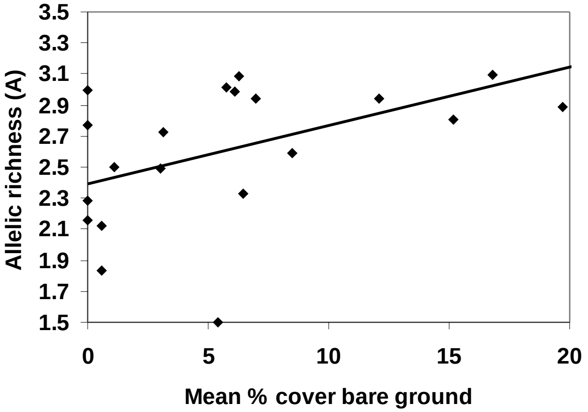

Fig. 2. The relationship between the mean percentange cover of bare ground and allelic richness (A) for 22 populations of *Cirsium dissectum*

Conclusions

Smaller populations of meadow thistle have a lower proportion of polymorphic loci. This reduction in genetic diversity could have negative impacts on populations, as small populations may be less able to adapt to changing environmental conditions. The results also show that the allelic richness is related to levels of bare ground. Bare ground may be important as it provides establishment gaps for seedling recruitment.

Jongejans, de Vere and de Kroon (submitted) found that seedling recruitment is incredibly rare in natural populations. This means that in sites with no establishment gaps, no seedling recruitment is taking place; as parent plants die, alleles can be lost. Small populations without bare ground are thus even more susceptible to loss of genetic diversity and management recommendations need to highlight the importance of creating establishment gaps.

Summary. These case studies illustrate some of the possibilities for conservation research into native species and habitats within zoos. This can take place at a variety of levels from maintaining a list of species found within zoo sites to conducting PhD research into important local habitats. By offering projects to undergraduate and industrial year placement students we are both contributing to the conservation of zoo sites and also helping to train conservation workers. Research is vital in order to monitor species and evaluate management but beyond this zoos can make a positive contribution to the scientific knowledge of rare species and habitats.

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Research for conservation – what a big zoo can and should do

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Abstract: The Centre for Research and Conservation (CRC), is the government-funded research department of the Royal Zoological Society of Antwerp (RZSA). Along the lines of the 2005 World Zoo and Aquarium Conservation Strategy (WZACS) the focal point of our research activities is sustainable population management. Both ex-situ and in-situ, managing populations sustainably requires the coordinated efforts of a whole range of research disciplines. Within the CRC we have gradually developed four diciplines where we combine strictly zoo-related research as well as fundamental scientific research. We report to scientists in peer reviewed journals as well as to zoo colleagues and to the general public. Our future plans are to initiate collaborative research projects with other zoo research departments, facilitate joint research projects and share research facilities and local expertise with zoos that don't have an in-house research team. Future joint applications for research grants from the European Union would be a next step forward for Zoo-research and zoo based conservation activities.

Key words: Centre for Research and Conservation; zoo research, conservation, sustainable population management

A brief history of research at the Royal Zoological Society of Antwerp

The Royal Zoological Society of Antwerp (RZSA) is 162 years old and currently comprises the Antwerp Zoo, Wild Animal Park Planckendael, the nature reserve 'De Zegge' and the Flanders Congress & Concert Centre. The Society's motto is 'Pro Natura et Scientia' and ever since its conception, science based working methods and research have played an important role in its activities. In historical times, research was rather opportunistic in nature and mostly focused on natural history, veterinary medicine and providing services to outside scientific institutions. Since the late sixties the need for more structured research activities resulted in a series of associations with the University of Antwerp and growing funding by the Flemish government, ultimately resulting in the employment of one full-time researcher in 1988. In 1992 a Scientific Advisory Board was established to supervise the quality of current research work and future research strategies, and additional research partners were attracted. Research was originally mostly focused on behaviour and on primates, but gradually studies in other disciplines and on other taxa developed. In time, the RZSA established its own research expertise and international research recognition. Ultimately, in 2002 this culminated in the establishment of our Centre for Research and Conservation (CRC), with modernised and expanded laboratory and veterinary facilities, made possible thanks to an increase in funding from the Flemish Government and continued partnerships with Flemish universities and research institutes, especially the University of Antwerp and the Institute of Tropical Medicine of Antwerp.

The current Research Department: Centre for Research and Conservation

The CRC, as the research department of the RZSA, is not a separate research institute, but is very much embedded in the structure and functioning of the Society. Research is concentrated in four disciplines: conservation biology, ethology, veterinary medicine and functional morphology. Each discipline has its own coordinator, responsible for the research projects within the discipline. The Scientific Advisory Board, with members from various departments of the University of Antwerp, the University Hospital of Antwerp en the Institute of Tropical Medicine (Antwerp) continue to supervise the research quality and strategy.

Conservation biology

The conservation biology department focuses on biological principles and their applications for the preservation of species, of biodiversity in general and the maintenance of equilibrium within ecosystems, and incorporates relevant ideas from ecology, population biology, genetics, biogeography, behaviour and a number of applied disciplines such as wildlife management and forestry. At the CRC, both in situ and ex situ projects are being carried out. At present, ex situ projects concentrate largely on those aspects of population biology related to the genetic, demographic and behavioural management of small populations of endangered species in zoos. So far the CRC has mostly worked with the RZSA's own international studbooks of the okapi (*Okapia johnstoni*), bonobo (*Pan paniscus*), golden-headed lion tamarins (*Leontopithecus chrysomelas*) and Congo peafowl (*Afropavo congensis*)), EEPs (European black vulture (*Aegypius monachus*) and ESBs (Mexican military macaw (*Ara militaris mexicana*) and Fischer's turaco (*Tauraco fischeri*)) but it is our full intention to expand to other species. Current DNA research projects are conducted on golden-headed lion tamarins, bonobos, European white storks (*Ciconia ciconia*), Cape seahorses (*Hippocampus capensis*), babirusa (*Babyrousa babyrussa*), Anoas (*Bubalus depressicornis* and *Bubalus quarlesi*), Sulawesi warty pigs (*Sus celebensis*) and spectacled bears (*Tremarctos ornatus*).

Where appropriate, the molecular laboratory of the CRC can also work to service the requirements of the other research units of the CRC, for example to determine the rate of extra pair copulations for the ethology unit, or to provide taxonomic work on infectious agents for the veterinary medicine unit. We also carry out all the sex determinations for animals in our own collections.

The in situ projects focus in particular on those animal species that are threatened with extinction and whose habitats have become highly fragmented or degraded. These studies involve both fundamental ecological research and more applied aspects. Some examples are the study of great apes and other primate species within a socio-ecological context like the Projet Grands Singes project in Cameroon; an 'Integrated Conservation and Development Project' that aims to develop a sustainable management plan for the community forests bordering on the Dja Faunal Reserve (DFR), and which – from a purely biological perspective – focuses on the socio-ecology of great apes in exploited areas (chimpanzees (*Pan troglodytes troglodytes*) and gorillas (*Gorilla gorilla gorilla*)). Further examples are projects on plant-animal interactions within an ecosystem, projects on the various impacts of commercial bushmeat trade, or on the consequences of forest degradation, as well as activities involving the planning and implementation of practical conservation measures such as landscape corridors and community forests, like the project ?BioBrasil? which aims to study the ecology and behaviour of golden-headed lion tamarins in fragmented and disturbed habitats.

Ethology

The ethology unit draws on a scientific approach to study and understand animal behaviour, with the ultimate goal to allow adequate management of zoo populations and to guarantee a species-specific behavioural repertoire in captivity. The research is focussed on the study of animal behaviour, with an emphasis on functional and evolutionary explanations of behaviour, and we pay special attention to the potential relevance of our research results for animal welfare and husbandry, for breeding programs, and for the sustainable management of populations in captivity. The research team of the CRC is quite unique within the zoo world in that over the years, with our research partners in universities and other research institutes, we have developed a routine of conducting behavioural research from an evolutionary perspective to identify underlying causes to 'symptoms' observed in our own breeding programmes, resulting in scientific peer-reviewed publications. The ethological research unit is the 'oldest' of the four and has so far produced seven successful PhD projects and four ongoing PhD projects.

Veterinary Medicine

Veterinary medicine is an integral part of animal welfare and is an essential ingredient for the optimal management of animal populations in situ and ex situ. In addition, reproduction and mortality rates are the main driving forces of population viability and veterinary medicine is essential for research into both of these fields. The veterinary unit of the CRC carries out research in practical veterinary medicine in the fields of pathology, microbiology, parasitology, haematology and biochemistry, serology, reproduction, nutrition and surgery. Examples of such research projects are the study of abortive agents in ruminants, microbiological evaluation of biofloors, identification, culture and treatment of gastrointestinal parasites, nutrition and digestion in various animals in the collections etc.

Other research activities encompass the early, in-vivo diagnosis of mycobacteria in zoo animals and epidemiology and control of gastro-intestinal nematode infections in captive wild ruminants, resulting in PhD-theses as part of a cooperation between the CRC, the University of Gent and the Institute for Tropical Medicine in Antwerp.

Functional Morphology

The relationship between form and function of animals is the subject of Functional Morphological research. The CRC has been able to acquire excellent facilities for a broad range of topics, such as modern dissection rooms in Antwerp and in Planckendael, and a range of multi-purpose scientific instruments (a multi-camera kinematic system, force transducers, pedobarograpic mats, high-quality goniometric and length transducers, etc.). The studied subjects are mainly apes, and two PhD projects are still ongoing at this moment, one on bonobos and another one on gibbons. Nevertheless, we are instigating new projects on the functional morphology of new species in collaboration with other institutions.

Topics directly related to the captive context have to date focused on claw problems in okapi (or ungulates in general). So far, this project has yielded preliminary results, but these do generate a lot of interest in the zoo and in the morphological/veterinary world. This type of research is crucial both to ensure good animal welfare and successful population management. Ignoring the evolutionary strategies of animals in terms of functional morphology within our husbandry systems may cause suffering to individuals, increased mortality, reduced longevity, decreased reproductive output etc.

Our and your future

Along the lines of the 2005 World Zoo and Aquarium Conservation Strategy (WZACS) the focal point of our strategic plan for scientific research in the coming next five years is sustainable population management. Both ex-situ and in-situ, sustainable population management requires the coordinated efforts of a whole range of research disciplines, not in the least the four disciplines we have gradually developed within our Centre for Research and Conservation: conservation biology, ethology, functional morphology and veterinary medicine. But to be able to tackle conservation issues worldwide in a scientific way we need to start cooperating on a grander scale within the zoo community and with universities and research institutes. One way forward would be to, on the one hand, initiate collaborative research projects with other zoo research departments, and on the other hand, facilitate joint research projects and share research facilities and local expertise with zoos that do not have an in-house research team (yet). Ideally, within Europe, for example, such collaborations could result in future joint applications for research grants with the European Union.

Web site details

Our strategic plan for research 2007-2011, the CRC year report for 2005 and further details on projects and publications can be found at the CRC web site:
http://webh01.ua.ac.be/crc/

Acknowledgements. We would like to thank all past and present staff, students, researchers and research partners of the CRC for their skills, enthusiasm and dedication that has helped shape our research department into the successful research group it is at the moment. The RZSA also gratefully acknowledges the structural support of the Flemish Government which over the years has been equally important to the 'story of our success'.

The introductory analysis of incidents involving captive animals during the 1990-2005 period

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Abstract: The knowledge concerning incidents involving the captive wild animals is to great degree anecdotal. In this paper the database of incidents in the world (with some unintentional overrepresentation of USA) during the last fifteen years was constructed. The source of information was the documentation from the Internet The database consisted of 481 cases which resulted in 530 human victims. The incidents occurred in zoos, circuses and other institutions (e.g. from entertainment and advertisement industry). Felids, elephants and primates were the chief animal culprits. Tiger (*Panthera tigris*) turned out to be the most dangerous as regards the number of incidents and as causing the greatest number of human victims .Elephants were ranked as the second, causing most of all human deaths. Surprisingly great number of cases involved also primates but they often caused rather minor injuries. They were eight situations where the incidents the most frequently took place. Intrude on animal, placing it in unfamiliar environment and lack of control and safety were the generalized underlying causes of incidents. This database should be supplemented by the fuller press reports to better understand particular cases (characteristics of the culprit and injured).

Key words: incident, captive animals, zoo, circus, big cats, elephant

Introduction

Owing the wild animal by human is always connected with certain risk. Even animal presumed tame can sometimes cause dangerous accident. There are well-known paradigms of professionals working in zoos and circuses. The incidents related to animals as sensations has played always specific role in the history and publicity about zoological garden (Baratay, 1998). Today the problem is more complicated. We witness the great popularity of keeping various wild (and often potentially dangerous) animals as pets, among others exotic reptiles and amphibians (Serpell 1999). Even big mammals are no exception. For example, there are probably as many as 15,000 private-owned exotic big cats in US (Handwerk 2003) Thus, despite the waning role of circus as regards performing and showing the captive animals, the number of wild animals in the world of men does not diminish.

On the other hand, the behavioural changes which took place in wild animals in captivity are still not sufficiently understood. The pioneering works of Hediger (1968) certainly elucidated some points , some models of behavioural change in captivity are also available (e.g. Carlstead 1996) but specimens variability, diversity of their housing conditions in zoological gardens and in the other institutions and often still limited knowledge concerning the biology and behaviour make predictions about, let say the given animal "degree of tameness" rather difficult.

In the recent literature there is lack of knowledge (particularly more comprehensive studies) concerning accidents caused by the captive animals. The information is often to great degree anecdotal. It would be interesting to estimate the number, species of culprits and the underlying cause of the incident. The present work is a small step to fulfill this end.

Material and methods

The source of information were Internet sites operated by pro animal rights organizations – People for Ethical Treatment of Animals and Animal Protection Institute (addresses: www.wildlifepimps.com and www.api4animals.org respectively.) As far as author knew these sites offered the most comprehensive review of incidents due to captive animals in the world based on the press reports. These reported events chronologically covered the whole years From the databases only the cases concerning incidents involving captive animals were selected . Thus, the incidents due to semi – wild animals (e.g. living in the national parks) and domestic or feral were excluded from this study. Also the incidents which not resulted in injury and/or death of human being were not taken into account. The databases comprised of incidents which took place during last fifteen years and this period was also used in the present study. The statistics was not used in this study since it was planned only as preliminary presentation at this stage.

Results and discussion

Animals implicated in incidents

On the basis of description in the Internet database the possibility of species identification was limited. Sometimes only vague categorization was used describing animal as "monkey", "lemur" or "python". The author had also sometimes trouble with the identification of the species of an elephant. Therefore, both species of these mammals were united for purpose of this study. The information concerning given animal was sparse. An age and life history were usually omitted ,with the exception of events when cat cub was mentioned. The sex was also only rarely specified. On the other hand, sometimes unexpectedly more precise information may be found in databases like "white tiger" or "black panther".

Mammals clearly dominated the group. There was only several reported incidents with the reptiles and captive wild birds we not represented in the database. This finding

Table 1. The list of captive mammal species causing incidents

Order	Family	Species	Common name
Carnivora	Canidae	Canis lupus	Timber wolf
	Ursidae	Ursus americanus Ursus thibetanus Ursus maritimus Ursus arctos Ursus malayanus	American black bear Asian black bear Polar bear Brown bear Malayan sun bear
	Felidae	Panthera tigris Panthera leo Panthera pardus Panthera onca Panthera uncia Acinonyx jubatus Neofelis nebulosa Felis concolor Felis serval Felis pardalis Hybrid (P. tigris x P. leo)	Tiger Lion Leopard Jaguar Snow leopard Cheetah Clouded leopard Puma Serval Ocelot
Primates	Lemuridae	Not specified (“lemur”)	Lemur
	Cebidae	Cebus sp. Ateles sp. Saimiri sp.	Capuchin Spider monkey Squirrel monkey
	Callitrichidae	Callithrix sp.	Marmoset
	Cercopithecidae	Macaca mulatta Macaca nemestrina	Rhesus monkey Pigtail macaque

		Macaca fascicularis	Crab-eating macaque
		Macaca fuscata	Japanese macaque
		Macaca radiata	Bonnet macaque
		Macaca sp.	Macaque
		Erythrocebus patas	Patas monkey
		Chlorocebus pygerythrus	Vervet monkey
		Papio sp.	Baboon
		Cercopithecus sp.	Guenon
		Not specified - (“monkey”)	
	Hylobatidae	Hylobates syndactylus	Siamang
Proboscidea	Elephantidae	Elephas maximus	Asiatic elephant
		Loxodonta africana	African elephant
Artiodactyla	Camelidae	Camelus sp.	Camel
	Bovidae	Not specified „buffalo”	

probably resulted from the fact that media coverage usually focus on more sensational incidents due to “dangerous” animals and ignoring the accidents caused by less impressive creatures. Some minor cases of this kind were probably not brought to light.

Therefore, in Table 1 only mammal species are shown. There were 30 identified species and several not fully defined. All fully identified species belonged to three orders: Carnivora, Primates and Proboscidea.

Number and place of incidents involving captive animals

On the basis of documentation from above-mentioned Internet sites 481 incidents with captive animals were found in the world during 1990-2005 period (see Table 2) The chief culprits as group (family) were the cats, elephants may be ranked as a second and primates as third. The tiger (Panthera tigris) was the cause of the greatest number of incidents – 116. As a whole the incidents took place mainly in zoological gardens but some other types of keeping wild animals (private ownership, entertainment industry etc) turned out to be also important. The number of accidents in circuses

Table 2. The number of incidents involving captive wild animals in the world during 1990-2005 period

	Number of incidents					
Site Species	Zoological garden	Circus	Other place	USA	Other countries	Total
Elephants	44	29	16	59	30	89
Tiger	46	21	49	94	22	116
Lion	22	14	19	31	24	55
Other cats	40	4	26	55	15	70
Bears	15	5	9	25	4	29
Chimpanzee	8	2	9	19	-	19
Gorilla	5	-	-	5	-	5
Other primates	25	1	55	79	2	81
Other animals	13	2	2	15	2	17
Total	218	78	185	383	99	481

may be seen as rather low and perhaps this is illustration of the rather waning role of this institution in keeping and showing the wild animals.

The incidents with tigers were the most frequent practically at all places: Thus, the keeping of this species in captivity seems to be highly risky. The elephants turned out to be dangerous both, in zoos and in circuses. This finding confirmed previous various reports stating that accidents with elephants happen with alarming frequency in captivity and national parks as well. For example Lehnhardt (1991) found that there was 15 fatal incidents caused by these animals in zoos between 1976 and 1991. The striking fact is also substantial role played in accidents by the primates, particularly monkeys at the places not classified to zoos and circuses. category (named as "others"). As regards the countries in which incidents took place there was probably overrepresentation of USA in the total number of events. This resulted from several facts: the specific role of US press in coverage of various accidents, and also from the simple fact that the number of wild animals kept by humans in the USA is probably larger than in the other countries

Human victim of incidents

In the present study contacts of men with the wild animals in captivity resulted in 530 human victims (see Table 3). Predominantly they were the consequences of animal attacks and only small number of events could be classified as accidental injuries. The

Table 3. Number of victims involved in captive animals attacks in the world during 1990-2005 period

	Incident result			Age of victim		Country		Total
	Injury	Death	Unknown	Young under 18 yrs	Adult	USA	Other countries	
Elephants Indian and African	67	35	4	18	88	73	33	106
Tiger	97	25	5	33	94	102	25	127
Lion	49	12	-	18	43	36	25	61
Other cats	69	5	-	21	53	56	18	74
Bears	25	3	3	6	25	27	4	31
Chimpanzee	24	-	-	7	17	24	-	24
Gorilla	7	-	-	2	5	7	-	7
Other primates	81	-	-	21	60	79	2	81
Other aniamals	16	1	2	6	13	15	4	19
Total	435	81	14	132	398	419	111	530

incidents involving animals caused injuries of various severity and 81 deaths The sequence of attack is often similar: pouncing on, dragging and mauling in the case of big cats, knocking to the ground in the case of elephants. As regards big cats and bears the biting on the leg or hand more often occurred Ultimate lot of some humans critically ill in the result of an animal attack were not précised in documentation. Hence, they were classified as "unknown". In the group of victim there was substantial number (nearly one fourth) of young persons in age under 18. The supremacy of victims recorded in USA over the other countries was also visible.

As may be expected elephants caused more human deaths than any other species. On the other hand, the humans with wounds inflicted by tigers composed the most numerous group of victims and also the most numerous group of youngsters.

Surprisingly great number of cases involved also primates but they often caused in humans rather minor injuries, like scratches or small bites.

Underlying causes of incidents involving captive animals

Since in many cases documentation of Internet databases is rather incomplete the discussion should concerns only hypothetical underlying causes of the incidents.

It is well-known fact that wild animal living in captivity preserves its natural behaviour patterns and uses them in reactions to its new environment. These reaction are often somehow distorted and depend on housing system limitations but basic behaviours listed in an ethogram are still the same. Thus, in zoo and circus an animal theoretically can perform among others territorial , social , agonistic behaviour which recipients are conspecifics and/or humans In predators more distorted is hunting behaviour which often has no outlet (Hediger, 1969)

On the basis of press report it was possible to reconstruct the incidents with captive animals, although only to some degree. Nine main causes of these events were proposed (see Table 4). Firstly, there is man intrusion on an animal . It is evident that in the case of elephants and big cats the situation when somebody from staff (e.g. handler, service

Table 4. The underlying causes of incidents involving wild captive animals (% of cases)

	Causes*								
Animal	1	2	3	4	5	6	7	8	9
	%								
Elephants	31	24	2	2	19	1	12	-	9
Tiger	25	13	12	3	12	7	-	8	20
Lion	26	14	17	2	8	14	-	7	12
Other cats	15	11	24	2	6	14	-	9	19
Cats Total	23	12	17	2	9	11	-	8	18
Bears	27	-	20	-	5	24	-		24
Primates	13	20	1	6	-	39	-	11	10

* – Causes: situations were classified as follows:
1 – Human enters the pen (handler, the staff members , service worker etc)
2– Animal escapes form the enclosure and attacks people
3 – Human approach cage/ placing hand in the cage/ attempt to pet or climbing to enclosure (visitors)
4 – Using animals in parades or leading them on leash
5 – Incidents during training session or performance
6 – Incidents with animals kept as pets being out of control
7 – Accidental injuries of humans e.g. fall down when riding on an elephant
8 – Using animals in exhibition, show, movie, commercial
9 – Others (pet shop, scientific institutions and situations not fully specified)

worker, etc) entered the cage and evoked an aggressive reaction. There are some possible motivational states of animal n this case: anger and offensive threat as an response to encroaching on the territory by human or fright when flight distance is disturbed by approaching man. Seeing human intruder as social rival is also the possible reason. Apart from an agonistic behaviour the previous animal abuse may be also seen as provoking animal aggression of this kind.

The disturbance by unknown person (visitor) either by placing the hand in the cage or climbing into enclosure had similar effect on the captive animal behaviour. In the case of predators hunting motivation is also possible. in this case. At the visitors side, it was striking fact that these events were very frequently recorded in the category of "other cats" (mainly cheetah, leopard , snow and clouded panther) and bears. All these animals may appear as cuddly to the visitors and for many irresistible as desired objects for physical contact.

Elephants turned out to be more prone to break out of control and to rampage with attacks often devastating.. These huge and powerful mammals are also very sensitive and have very good memory (Rensch, 1957) which explains their unpredictability. Ironically, much smaller but also intelligent and agile primates also escaped frequently from the cages. Feeling of insecurity and fear which stems from being in unfamiliar environment seems to be the typical mental states in this case. In this situation aggression may be triggered like in similar cases of parades, shows, movie and commercial sessions etc (see Table 4).

The training of captive animals in circus is usually complicated phenomenon when some behaviouristic techniques are linked with certain mutual trust and bond between animal and trainer (Kiley-Worthingotn 1995). However, the sudden bursts of aggression during performance or training were ascertained in this study in elephants and big cats. The trainer was usual victim but sometimes also the other persons were injured. Since the animals are very sensitive to human non verbal communication signals trainer mistakes or even subtle changes in disposition may cause an accident. Of course an animal abuse and changing psychic condition of animals often has the same effect on aggression versus man.

The other problem is keeping wild animals as pets. It seems that private ownership of large felids creates significant public consequences. This study confirmed this supposition: the presence of these animals in human communities in USA really endangered neighbours, domestic pets and others. In incidents caused by primates keeping them as pets played also significant role. It seems that at the owner side the humanization of pet as a family member and underestimation of its unpredictability often leads to an accident.

However, as a whole it is need to see at the incidents provoked by the captive wild animals from a broader perspective. It should be underlined that the human casualties caused by the captive animals seems completely insignificant against the background of the other incidents. For example in USA only in 2002 there were 43,000 persons which died in car accidents (www.car-accidents.net), over 14,000 murder victims (www.fbi.gov) and 520 deaths resulted from fires (www.ufa.fema.gov). Even the comparison with the incidents caused by domestic animals is instructive. For example, the number of domestic dog bites and scratches victims is estimated each year as 1% of US population. (Serpell 1999)

The author is aware of the present study limitations. Firstly, only the partial list of incidents involving captive animals in the world was analyzed with the bias to the events which happened in USA. Supposedly, some minor cases have been ignored and not reported by press or even concealed by staff or authorities. Secondly, the press information cited by Internet sites was often not sufficient for the more profound analysis of material characteristics and an incident cause. Thus, the press material should be thoroughly reviewed .Thirdly, the factorial analysis of incidents based on verified material is needed to answer questions how elements of described events are interrelated.

Conclusions

Internet sites databases as a sources of information concerning incidents involving animals turned out to be useful but should be supplemented by fuller press report with the characteristic of the culprit and victim. In the present study there were 381 incidents with 530 human victims in the world during the last fifteen years but this list is probably far from complete. Elephants and big cats turned out to be the most dangerous captive animals causing incidents with tiger (Panthera tigris) as the really high risk species

The typical situations in which incidents took place were divided into nine groups but this division may be simplified. Humans disturbing caged animals in some way either as familiar (e.g. handler) or unfamiliar objects(e.g. visitor) played the significant role in provoking animal aggression. Probably human overconfidence about an animal “tameness”, ignorance as regards its behaviour , and inconsiderateness were behind these accidents. Also placing animal in unfamiliar environment when they are used in various shows, performances, movie and commercial sessions often resulted in the same way. The third important theme in incidents due to captive animals is lack of control and safety in handling which enabled an escape and following aggression.

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Evaluation of selected educational opportunities of animal exhibitions in zoological garden based on a case study

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Abstract: The aim of the hereby research was to identify the criteria influencing the educational value of animal enclosures. Next, the criteria were used to evaluate 11 selected exhibitions of chimpanzee (Pan troglodytes) and bonobo (Pan paniscus) in different zoological gardens. The criteria were identified during two-stage cameral analysis, which included project, behavioural and organisational assumptions. The analysis provided 52 criteria divided into 9 groups: area size, vegetation, water, ground (relief), landscape (shaping of visibility), arrangement, equipment components, microclimate, animals. The criteria were then used to evaluate the exhibition using an ordinal scale (-1, 0, +1). The total result indicated the best designed and arranged exhibitions with highest educational value in Münster and Cologne. Criteria from the groups: area size, landscape (shaping of visibility) and arrangement were the key points for evaluating the educational value o fan exhibition. High notes obtained for these groups of criteria had positive influence on other criteria. Moreover, it was proved that a criteria from groups: landscape (shaping of visibility), arrangement and vegetation are decisive creation of a “natural” barrier between the visitors and animals, which harmonised with the surrounding landscape.

Key words: zoological garden, exhibitions, education, transmission of information, landscape replication

Introduction

Zoological gardens have various roles: educational, recreational, scientific, conservation (preservation of endangered species) and protecting genetic resources of animals (diversity). Education is among the most significant roles and may include environment protection programs presenting dangers to various species, relations between economy, lifestyle and natural environment with its resources (Olech 2003). However, the most important aspect of the zoo’s educational role is presenting animals and their behaviour in environment similar to natural. Presentation of the complexity of an ecosystem: environment, animals, interrelations and interactions can have influence on the society’s educational awareness. It is estimated that American zoological garden are visited by over 104 million visitors every year (AAZPA 1992) while 14 Polish zoos are visited by 2.5 million individuals annually (Topola 2004). Assuming that every average visitor spends 2 hours in the zoo and that every minute they learn (consciously or subconsciously) 1 piece of information, the number of educational opportunities is about 12.5 billion for American zoos and 300 million for Polish zoos (Coe 1987). Moreover, a visit to zoo is a direct and real experience and not TV fiction. It is also important to mention that, according to Joslin's et al. (1986), research in Chicago zoo, 80% of visitors are children under 10 years of age with parents.

Nowadays, during the design phase or rearrangement of animal exhibitions, the needs and safety of animals as well as the visitors' safety are among the top priorities. Unfortunately, the first impression and imitation of the natural environment are neglected. Even exhibitions which satisfy all the needs of animals, often give the visitors a wrong idea about the natural habitat of the animal. Creating the impression of an animal being shown in a fragment of its natural habitat is often wrongly implemented or even totally omitted. An example of that trend could be a multi-level enclosure for great apes equipped with lines, nets, a variety of plastic buckets, cardboard boxes and rags, which certainly encourage the animals' behaviour. They are able to move on different heights, play around and build rag dens every evening. Although the visitors (children) must be delighted to see a pack of apes playing around, they might be mislead about their natural habitat which they might imagine as a kind of rubbish dump (Polakowski 1987).

The information provided above indicates that there are huge possibilities for zoological gardens to influence environmental awareness of the society. This was included in the hereby article as analysis of educational role of chimpanzees exhibitions. This evaluation will be focused on exhibitions and their functioning and special attention will be given to the impression (information) which the visitors may acquire themselves having seen a given exhibition. All the information facilities located in the visitors' area (information boards, models, educational corners with artistic presentations) will not be described in this article The aim of this evaluation is to identify the exhibitions with the best arrangement and highest educational value as well as to answer the question *Which criteria have the most influence on the educational value of an exhibition?*

Method of research

The subject of research was analysed based on a number of information and data obtained in theoretical research (chamber) and outdoor research. The first type was two-stage research using analysis of content method (Cartwright 1965). The starting point in the analysis identifying the set of criteria were 3 ideas creating an educational message: context, content and message (Coe 1987). The second stage of theoretical research included review and analysis of publications to identify behavioral (Chamove *et al.* 1982, Coe 1985, Estes 1991, Goodall 1978), project (Blaser 2001, Coe 1994, Nash 1982, Pinxten 1999, Polakowski 1987, Shepherdson 1988, Tierschutz 2002), and organizational assumptions (Coe 2004, Nogge 1985, Polakowski 1987). This resulted in identification of 52 criteria divided into 9 groups such as: area size, vegetation, water, ground (relief), landscape (shaping of visibility), arrangement, equipment components, microclimate, animals.

Table 1. Criteria for evaluation of chimpanzee and bonobo exhibitions – results of content analysis in publications

Group	Number	Criterion
Area size	A.1	Is the external enclosure larger than 300 m^2?
	A.2	Is the internal enclosure larger than 100 m^2?
	A.3	Is the area of internal enclosure larger than $25m^2/80m^3$ for each chimpanzees?
Vegetation	B.1	Do plants cover over 25% of the exhibition area?
	B.2	Is vegetation in the exhibition similar to vegetation in chimpanzees' natural environment?
	B.3	Is vegetation in good condition?
	B.4	Is part of the vegetation accessible to animals?
	B.5	Can chimpanzees climb on trees?
Water	C.1	Is reservoir in the external enclosure?
	C.2	Is the exhibition surrounded by water (moat)?
Ground (relief)	D.1	Is the area slightly rough? Are there hills and hollows?
	D.2	Is water access slightly sloping?
	D.3	Is the enclosure's area covered with grass?
	D.4	Is the surface of the enclosure covered with wood bark, sawdust or bedding?
Landscape (shaping of visibility)	E.1	Do visitors watch the animals from view spots hidden behind plants?
	E.2	Is it possible to watch the animals from different altitudes?
	E.3	Are visitors on one viewing spot not visible from other viewing spots?
	E.4	Does arrangement of the exhibition allow for watching the animals with other exhibitions or animals in the background?
	E.5	Are the animals shown with vegetation or other natural forms in the background?
	E.6	Attention of visitors on the viewing spots should be directed to one exhibition
	E.7	Is the exhibition surrounded by plants or other natural screen so that the animals are not visible from each side (animals cornered by visitors)?
	E.8	Visitors should not be mislead about the chimpanzee' natural habitat (landscape)
	E.9	Is the sunlight behind the visitors' back while watching the animals?
Arrangement	F.1	Do visitors walk into the area occupied by an animal (e.g. the viewing spot is surrounded by the exhibition)?
	F.2	Do visitors try to spot the animals?
	F.3	Are visitors at the outer edges of exhibition and animals in its centre?
	F.4	Is the exhibition arranged in the way that viewers may be surprised by unexpected appearance of an animal?
	F.5	Do viewers watch the animal in surroundings similar to natural?
	F.6	Do viewers watch the chimpanzees without any visible barriers between them?
	F.7	Is it possible to watch the animals at close distance?
	F.8	Exhibition should not be predictable for visitors
	F.9	Is there a possibility for the animals to hide from the visitors and alienate from other apes?
	F.10	There is a possibility for the animals to move on different altitudes
	F.11	Does the arrangement of the enclosure allow quick rearrangement?
	F.12	Is there a possibility to change the size of the exhibition?

Equipment components	G.1	Using artificial termite mounds or hollow tree trunks with food, which makes the animals use self-made tools (f.e. sticks0 to get the food out
	G.2	Are some types of food served by hiding them under the bedding or in the trees?
	G.3	Large number of attached lines, nets, mats styled to resemble natural elements as well as loose items in the exhibition (pieces of wood, tree trunks, branches)
Microclimate	H.1	Is the temperature during the day constant (23 - 24^{0}C)?
	H.2	Is there an operating ventilation system without marginal areas of air stagnation?
	H.3	Is the internal enclosure water-sprayed so that air humidity is about 80%?
	H.4	Enclosure should not have northern exhibition
	H.5	Enclosure should not be sloping from the North (cold air flow)
	H.6	Is the internal exhibition lightened also with natural light?
	H.7	Are the animals able to stay in the sunshine during all day?
	H.8	Is approximate 30% of the internal exhibition shaded?
	H.9	Is the internal exhibition shade not covered over 60% of exhibit area
Animals	I1	Are chimpanzees presented in groups of at least nine specimens?
	I.2	Do the animals reproduce?
	I.3	Do the animals solve conflicts themselves without fighting?
	I.4	Is the observed behaviour similar to natural?
	I.5	Is there no abnormal behaviour (stereotypical or pathologic)?

The outdoor research included inspections in 11 zoological gardens in the years 2002-2003, during July and August. The exhibitions in question are found in 6 European countries: Poland, Germany, Great Britain, Belgium, Switzerland, and Denmark. The data for research was collected in all zoological gardens with chimpanzee exhibitions which were visited by the author during work on this and other research projects. Selection of subjects for research was guided by information from publications as well as specialist guidelines from research centres (zoological gardens, EAZA). Actually the subject of outdoor research were 11 chimpanzee exhibitions located in Wrocław, Berlin (Berlin Zoo), Frankfurt am Main, Hannover, Cologne, Münster, Wuppertal, London, Antwerp, Basel, Copenhagen.

Fig 1. The exhibition is arranged in the way that viewers may be surprised by unexpected appearance of an animal – zoological garden in Cologne

Fig 2. The exhibition is surrounded by plants or other natural screen so that the animals are not visible from each side (animals cornered by visitors) – zoological garden in Cologne

During the inspections, exhibitions were measured, described and photographed, animal behaviour was observed and local specialists were consulted to determine criteria.

All observations took place at the same time of the day (10.00, 13.00 and 18.00 hrs) for one hour at a time. Three periods of observation were necessary to obtain the average daily behaviour of animals, that is a preliminary etogram (Shepherdson 1989). Based on the observed behaviour, the educational role of individual exhibitions can be evaluated.

Fig 3. The exhibition is surrounded by water (moat) – zoological garden in Münster

Data gathered during the research was analysed according to 52 criteria measure in an ordinal scale (-1, 0, +1), -1 stands for unacceptable conditions (bad), 0 – intermediate, +1 – proper conditions (good).

The final educational value was determined having the total value of all criteria for every exhibition for chimpanzees and bonobos. There were applied identical criteria for both species because are no significant differences in educational value in between them. The content of criteria and evaluation method were determined according to information from publications and consulting local specialists in zoological gardens. Consultations included surveys and latest information obtained in each zoo. The survey consisted of several question groups: general information, light, vegetation, relief, ground (surface) and functioning of exhibitions.

Results

The maximum total number of points was 52 points and the lowest possible result – 52 points. The zoo in Münster scored the highest (38 points) and the zoo in Frankfurt am Main scored the lowest (-29 points). Results of the educational evaluation allow for dividing the zoological gardens in question into four groups:

- high educational value: Münster 38, Cologne 28
- moderate (acceptable) educational value: Hanover 4
- bad educational value: Wrocław -7, Copenhagen -8, Basel -12, Berlin -14
- very bad educational value: (misleading educational message): Wuppertal -16, Antwerp -26, London -28, Frankfurt am Main -29

Table 2. Results of outdoor research concerning evaluation of the educational value of chimpanzee (Pan troglodytes) and bonobo (Pan paniscus) exhibitions in 11 European zoos (* bonobo exhibition)

		Cities in which are located zoological gardens with researches exhibitions										
Group	**Criterion number**	Wrocław	Berlin zoo	Frankfurt am Main*	Hanover	Cologne*	Münster	Wuppertal*	London	Antwerp	Basle	Copenhagan
Area size	A.1	1	1	-1	1	1	1	-1	0	-1	-1	-1
	A.2	1	1	0	0	1	1	0	-1	0	1	1
	A.3	1	0	-1	0	0	0	0	-1	-1	0	1
	A	**3**	**2**	**-2**	**1**	**2**	**2**	**-1**	**-2**	**-2**	**0**	**1**
Vegetation	B.1	1	1	-1	-1	1	1	-1	-1	-1	-1	-1
	B.2	-1	-1	1	1	1	-1	1	-1	0	0	1
	B.3	1	1	0	1	1	1	1	0	-1	-1	1
	B.4	1	0	-1	-1	1	1	-1	-1	-1	-1	-1
	B.5	1	-1	-1	-1	1	0	-1	-1	-1	-1	-1
	B	**3**	**0**	**-2**	**-1**	**5**	**2**	**-1**	**-4**	**-4**	**-4**	**-1**
Water	C.1	-1	-1	-1	1	-1	1	-1	-1	-1	-1	-1
	C.2	0	0	1	0	-1	1	-1	-1	-1	-1	1
	C	**-1**	**-1**	**0**	**1**	**-2**	**2**	**-2**	**-2**	**-2**	**-2**	**0**

Ground (relief)	D.1	0	-1	-1	1	-1	1	-1	-1	0	-1	0
	D.2	-1	-1	-1	1	-1	1	-1	-1	-1	-1	1
	D.3	1	1	-1	1	1	1	-1	-1	-1	-1	-1
	D.4	-1	-1	1	-1	1	1	-1	-1	-1	1	-1
	D	**-1**	**-2**	**-2**	**2**	**0**	**4**	**-4**	**-4**	**-3**	**-2**	**-1**
Landscape (shaping of visibility)	E.1	-1	-1	-1	-1	1	1	-1	0	-1	-1	-1
	E.2	-1	-1	-1	1	-1	0	1	-1	-1	0	-1
	E.3	-1	-1	-1	0	1	1	-1	0	-1	-1	-1
	E.4	-1	-1	-1	-1	0	1	-1	-1	-1	-1	-1
	E.5	0	0	-1	0	1	1	-1	-1	-1	-1	-1
	E.6	1	1	0	1	1	1	1	0	1	1	1
	E.7	-1	-1	-1	0	1	1	-1	-1	-1	-1	-1
	E.8	-1	-1	-1	-1	0	0	-1	-1	-1	-1	-1
	E.9	0	0	-1	1	1	1	-1	0	-1	0	-1
	E	**-5**	**-5**	**-8**	**0**	**5**	**7**	**-5**	**-5**	**-7**	**-5**	**-7**
Arrangement	F.1	-1	0	-1	0	1	1	0	-1	-1	-1	0
	F.2	0	-1	-1	-1	1	1	-1	-1	-1	-1	-1
	F.3	1	0	0	1	1	1	0	1	0	0	1
	F.4	0	-1	-1	-1	1	1	-1	-1	-1	-1	-1
	F.5	0	-1	-1	-1	1	1	-1	-1	-1	-1	-1
	F.6	-1	-1	0	-1	1	1	0	-1	0	0	0
	F.7	0	0	1	1	1	0	1	0	1	1	1
	F.8	0	-1	-1	-1	1	1	-1	-1	-1	-1	-1
	F.9	0	-1	-1	0	1	1	-1	-1	-1	-1	-1
	F.10	1	1	1	0	1	1	1	1	1	1	0
	F.11	0	-1	-1	0	1	1	-1	-1	-1	-1	-1
	F.12	0	-1	-1	-1	1	1	-1	-1	-1	-1	-1
	F	**0**	**-7**	**-6**	**-4**	**12**	**11**	**-5**	**-7**	**-6**	**-6**	**-6**
Equipment components	G.1	-1	0	-1	-1	-1	-1	-1	0	1	1	1
	G.2	0	0	1	1	1	1	1	1	0	0	1
	G.3	0	0	0	-1	1	1	-1	-1	0	0	-1
	G	**-1**	**0**	**0**	**-1**	**1**	**1**	**-1**	**0**	**1**	**1**	**1**
Microclimate	H.1	0	1	0	1	1	1	1	-1	1	1	1
	H.2	-1	1	-1	1	1	1	1	-1	0	0	1
	H.3	-1	1	-1	1	1	0	1	-1	0	1	0
	H.4	-1	-1	-1	0	1	1	-1	0	-1	0	-1
	H.5	-1	-1	-1	1	1	1	-1	1	-1	-1	-1
	H.6	-1	-1	-1	0	0	-1	1	-1	-1	0	1
	H.7	1	0	0	1	1	1	-1	1	-1	0	-1
	H.8	1	0	-1	0	1	1	0	-1	0	0	0
	H.9	1	0	-1	0	1	1	0	1	0	0	0
	H	**-2**	**0**	**-7**	**5**	**8**	**6**	**1**	**-2**	**-3**	**1**	**0**
Animals	I1	0	0	-1	0	0	1	0	-1	1	1	1
	I.2	-1	-1	-1	-1	-1	0	0	-1	1	1	1
	I.3	-1	-1	-1	1	-1	1	1	1	0	1	1
	I.4	0	0	0	0	0	1	0	0	-1	1	1
	I.5	-1	1	1	1	-1	1	1	-1	-1	1	1
	I	**-3**	**-1**	**-2**	**1**	**-3**	**4**	**2**	**-2**	**0**	**5**	**5**
Sum		**-7**	**-14**	**-29**	**4**	**28**	**38**	**-16**	**-28**	**-26**	**-12**	**-8**

The above results may indicate that chimpanzees exhibitions in Münster and bonobos in Cologne meet most of the requirements and convey the right information about the chimpanzee and its environment to visitors. It might be interesting to notice that the exposition in Copenhagen, despite it was built in 1994, does not meet even the minimum requirements for educational values. It might be caused by the lack of external enclosure and keeping animals in “sterile, laboratory-like” conditions.

The results obtained by other exhibitions clearly indicate that their educational message may be harmful and misleading. It is important to notice that the exhibition in Wrocław scored better than other exhibitions with poor educational value (-7) probably due to the large size of its external enclosure covered with good condition vegetation

Conclusions

1. Area size, landscape (shaping of visibility) and arrangement of the enclosure are key factors influencing the educational value of an exhibition. In many cases positive interconnections may be noted between other criteria (if those criteria are of high value other will have high value as well). The Münster and Cologne exhibition illustrates this tendency as its large area influences the criteria from vegetation and landscape (visibility shaping) groups.
2. The large size of external enclosure allows to create an exhibition which may reflect natural habitat of the chimpanzees and, at the same time, present them in a better way.
3. Criteria from groups: landscape (visibility shaping), vegetation and water are decisive creation of a “natural” barrier between the visitors and animals. The analysed zoos in Münster and Cologne which scored high for those criteria used solutions harmonised with the surrounding landscape.
4. The method of research used hereby, proved to be effective in evaluating the educational value of chimpanzee exhibitions in zoological gardens but it isn’t fully to answer the questions asked. Thus the method could be improved by using a greater number of criteria with different ranks, a criterion referring to natural environment and a questionnaire for visitors (did the actually remember what we intended to teach them).

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Theoretical bases of environmental enrichment as applied to keeper-animal interactions

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Abstract: The working model of zoo environment enrichment has been elaborated. This model is based on the concepts of "optimal arousal level" and data concerning the influence of predictability and controllability of environment on animal's sensitivity to external stimulation. According to this model a functional classification of enrichment tools and an algorithm for choosing such tools are suggested. The efficiency of our approach was tested in Moscow Zoo's practice. Special emphasis was made on keeper-animal interactions as a tool for enrichment and improvement of animals' psychological state.

Key words: environmental enrichment, zoo animals, controllability, predictability, stress, optimal arousal level, keeper-animal interactions

Introduction

Environmental enrichment as a way to increase zoo animals' welfare has become very popular over the last three decades (Meyer-Holzapfel, 1968; Markowitz, 1982; Broom, 1988; Boissy, 1995; Young, 2003). In spite of a great deal of applied zoo environmental enrichment research, its theoretical background still hasn't attracted enough attention and "…many key concepts have yet to be refined or discovered" (Shepherdson, 1998). At the same time such background may be very useful for adequate choice of enrichment tools and for the elaboration of new ideas. We took the theoretical bases of environmental enrichment in classic ethology and stress concepts; elaborate the model of enrichment (through manipulations with animal's control and predictability of environment) and to apply this model to keeper-animal interactions.

Material and methods

We created our model using some published research and then tried to test and apply it to the conditions of Moscow Zoo.

We define “zoo environment enrichment” as any impact leading to improvement of animals’ psychological state.

Discussion and Results

The first source of environmental enrichment theoretical bases is the well known concept, that being in captivity animals want some species-specified stimulus (releasers and others similar to them). So, while enriching animals’ environment, we should try to fill up this lack of special stimulation. Good examples of such approach are the experience of ornithologists from Moscow Zoo who succeeded in breeding some bird species (night herons, some geese and peafowl) in 1950-1955 after giving them species-specific nesting releasers (unpublished data).

However releasers-stimuli application can’t be used on a daily basis due to of lack of possibilities in captivity and sometimes unobviousness of animal’s needs. The main stream of enrichment is increasing novelty and providing objects for keeping animals busy. There are a lot of examples and methods for such kind of enrichment, but there isn’t any presumptive model which may help zoo stuff to choose the best tools with predictable results. To solve this problem we tried to elaborate a special working model. This model is based on concepts of: “the optimal level of stimulation” (Lebua, 1955) or “the optimal arousal level” (Hennessy, Levine, 1979) which postulate the existence of individual-specific (or species-specific) level of stimulation (and hence arousal, and hence stress) when animals can cope in an optimal way. If real stimulation is significantly lower than this optimum level for a long time then it may lead to apathy and lack of activity or destructive behaviour directed onto enclosure, otherwise if stimulation – arousal – stress is too high then distress comes with all its pathological features.

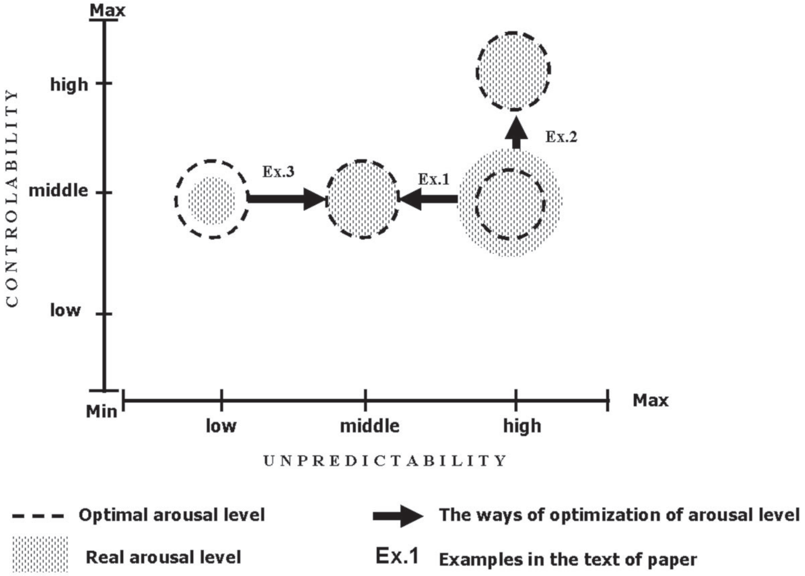

Fig.1. The model of optimal arousal level achievement through manipulations with controllability and predictability

Also, they made it clear that even a weak stressor has worse effect if it is a) unpredictable and/or b) uncontrolled (Weiss, 1971; Davis, Levine, 1982; Herbert, 1987; Hennessy, Foy, 1987).

So, our model (Fig. 1) shows interactions between these characteristics: the two scales are the predictability of environment and the available level of control, and the fill areas in the space of scales denotes the arousal (and stress) level.

The general plan for assessment of state of animal with abnormal behaviour is illustrated in following table.

SYMPTOMS	CONCLUSIONS
Vacuum instinctive activity	**THE LACK OF SPECIAL STIMULUS REALIZING INSTINCTIVE BEHAVIOUR PATTERNS**
Timidity, hysterical behaviour, stereotypes with high speed of performance, hypertrophied defensive behaviour; decrease of exploratory activity and grooming, decrease of sleep-activity circle fickleness; the hair becomes disheveled; there is diarrhea and weight loss.	**THE LACK OF CONTROL IN CONJUNCTION WITH HIGH ENVIRONMENTAL UNPREDICTABILITY**
Decrease of total level of activity, decrease of animal behavioral diversity. Appears apathy and at the same time fit of destruction activity towards zoo decorations, aggression directed at keepers, increased rate of stereotypes with low speed of performance.	**THE LACK OF CONTROL IN CONJUNCTION WITH TOO LOW ENVIRONMENTAL UNPREDICTABILITY**

When we access the arousal level as too high (for example, an animal has arrived recently or stressed after some manipulation) it may be lowered through increasing of predictability – using stable husbandry regime, warning signals before routine procedures; or we may lower the level of stress by increasing an animal's opportunity to control its environment – give it freedom to choose the intensity of stimulation by using refuges, "observation posts", place objects for manipulations at its disposal and so on.

Example 1. Animals are not so nervous in situations of aversive blood sampling if they have been acquainted with the procedure and got a previous signal (Grandin et al., 1995)

Example 2. The male of armadillo *Chaetophractus villosus* became hard stressed when he was placed in quarantine enclosure of Moscow zoo: he rushed about the cage and refused to eat at all. All these symptoms disappeared just after we put much more hay into the cage. The armadillo could shelter in it and manipulate (Neprintseva et al., 1999).

If we access the arousal level as too low then we can increase it by introducing unpredictable novelty into the animals' environment, such as a new design, an unfamiliar stimulus or new social partners.

Example 3. Slot bear male decreased level of stereotypy about 20% as result of feeding by boxed food and opportunity of interaction with female through the mesh (Neprintseva *et al.*, 2005).

According to this model we can subdivide all tools of zoo environment enrichment to:

a) promotional to decrease unpredictability
b) promotional to increase unpredictability
c) promotional to increase control of environment

Then we need to complete this index with:

d) special stimuli realizing instinctive behavior patterns

And the resulting list may be good background for the following functional classification of tools for enrichment.

Functional classification of tools for enrichment

1. Special stimuli realizing instinctive behavior patterns

   Changes the degree of animals environment predictability

2. Increasing of predictability
   - 2.1. stable husbandry regime
   - 2.2. warning signals before routine procedures
   - 2.3. decrease of contacts with visitors
3. Decreasing of predictability
   - 3.1. providing with new objects
   - 3.2. feeding procedures
     - 3.2.1 changes in feeding regime
     - 3.2.2 interchange of different food
     - 3.2.3 different ways of food providing
   - 3.3. providing with new stimulation from other animals
     - 3.3.1 sounds
     - 3.3.2 visual stimuli
     - 3.3.3 olfactory stimuli
4. Increasing of animal environment control
   - 4.1. through enclosure design which lets the animals to choose kind and volume of stimuli
   - 4.2. through disposal objects for manipulations
     - 4.2.1 material for developing of individual space
     - 4.2.2 special toys, playing machines and problem boxes
   - 4.3. social enrichment
   - 4.4. men-animal interactions
     - 4.4.1 visitors
     - 4.4.2 keepers

In the next part of this article we would like to specify the last position and analyse keeper-animal interactions during keeping routine procedure from the view of our model. This particular enrich tool was chosen because of the following reasons. Firstly, the keeper is the most important and flexible element of the zoo animal's environment. Secondly, keepers can show different styles of behavioral techniques during the keeping routine procedure. Physical and psychological welfare of an animal can be significantly influenced by a keeper's behavioral patterns (Mellen, 1991, Mellen et al., 1998; Neprintseva *et al.*, 2000). Thirdly, consideration of differences of keepers' behavioral patterns makes it possible to reveal how different styles of keepers' interactions with animals form the animal's environment (Neprintseva, 2004; 2005).

Two cases concerning routine procedures with two species of mammals were analysed. We described the keepers' behavioral patterns in terms of control and predictability manipulations.

Case 1

Case 1 concerned the behavior of two keepers toward isolated wart hog (*Phacochoerus aephiopicus*) male being kept in two weeks quarantine after being transferred to our zoo. This animal was stressed after changing its housing conditions.

During the first week, this wart hog male was looked after by Keeper 1, who applied invariable routine keeping procedure during all the week. Keeper 1 used "prelude" before animal separation, which consisted of quiet talking to wart hog during 5 min. Then the animal was given the opportunity to move into a separate enclosure and eat some food which had been put there in advance. The keeper didn't hurry the animal. Time for this work depended on an animal's state and sometimes ran up to 30 minutes, but usually animal came into separate enclosure after 15-20 min. There he remained calm when keeper closed the door after him.

During all this period the wart hog male demonstrated successful adaptation to new housing conditions and showed adequate behaviour. Sometimes Keeper 2 was present at the keeping procedure to give the animal possibility to adapt to unfamiliar person.

So, keeping style of Keeper 1 compensated high level of unpredictability in unfamiliar environment by improving of animal's control opportunity and decreasing of environment unpredictability. Experienced keeper intuitively used techniques, which can help the animal to maintain the optimal arousal level. The "prelude" and constant keeping procedure was predictable and increased the predictability of environment for wart hog. Keeper 1 applied some "passive" behaviour and took into consideration animal's state. This human behaviour allowed the animal to control aversive stimulation.

At the beginning of the second week this situation was dramatically changed for one day. Keeper 2 without any "prelude" opened the door into the separate enclosure and waited about 5 minutes. When the wart hog didn't go into enclosure Keeper 2 began to prompt him to do it with his voice-activated control. His attempt was not sucsses and he needed to ask for help. Throughout next 5 minutes two keepers drove the animal into separate enclosure and closed the door. Wart hog displayed high arousal: the animal began to toss about the enclouser and pushed the door. 30 minutes later he became obviously distressed: his grooming patterns were disturbed, he tried to escape and became very aggressive to people (including both keepers).

Those alterations lasted during all week and didn't disappear when the routine procedure was restored.

The change of keeping procedure caused additional stress. This seemed to have been caused by a lack of the animal's control of aversive influences.

Case 2

This case concerned the behaviour of orangutans (*Pongo pigmaeus*) kept in exhibition during the first two weeks of their pair formation.

During the first week both orangutans were put into one separate enclosure during clearing of their enclosure, since both male and female often initiated copulation and tried not to be separated. Then female sometimes began to avoid copulations. Her attempts were more successful in a bigger enriched exposition enclosure then in smaller simple separate one.

One of the keepers (Keeper 3) did not pay attention to these changes in female's behaviour. To save his time he went on locking the animals together in the small separate section. Very soon the female began to display the signs of discomfort and anxiety which was quite undesirable for pair formation. She refused to enter the small section and preferred to stay in big exposition enclosure, where she could control her interactions with male. Thus Keeper 3 still further decreased the possibilities of female's environment control.

Then Keeper 4 tried to change the situation and to help female in her attempts to avoid the male and he isolated animals in two separate small enclosures. It looked as "a collusion" with the female. The female became more self-reliant and the aimals' bond was normalized. The technique of Keeper 4 allowed the female to control her social environment.

So, if the animal is affected because of high level of stimulation keeper can optimise this level by his responsive manner of keeping. Experience keeper seems to be the part of zoo environment, which is responsive and so controlled for animals.

Conclusion

Considered model, which of course requires criticism and further elaboration, however was found to be useful for classification of empirical enrichment methods and for working out the "choice laws" of using these methods. The practice of Moscow Zoo group for environment enrichment showed efficiency of such approach.

So, according to our view the goal of zoo environment enrichment is to supply animals with species-specific realesers and to provide every animal with the ratio of predictability and controllability of its environment to get the optimal stress level. We think it is the real way to improve animal's psychological state. That makes the understanding of the word "enrichment" broader. A keeper is a controlled part of zoo animals' environment if he meets their needs. He provides the necessary balance of predictability and controllability during routine keeping.

In fact, the keeper has many potentialities to control animals' behaviour without lowering their well-being. It is possible for him to maintain constantly the necessary level of unpredictability, for example by slight changing of routine maintenance procedure. Many keepers intuitively use the technique of permanent "routine enrichment" in their daily work.

At the same time, it is possible for the experienced keeper to guess right what is the most necessary to the animal at that very moment – a feeling of control or the requirements of a novelty. The keeper with such tactic becomes a source of environment enrichment for animals.

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Keeping of *Cervidae* in Lithuanian Zoo

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Abstract: *Cervidae* are an ecologically important group of animals. Their keeping in captivity arouses many various problems, especially of moose, reindeers, roe deer and others. The proper feeding of these animals is very important in the zoo, for example, moose eat leaves, small branches and bark of lot sorts of trees and bushes in the wild. Lichens are very important part of the ration of the reindeers, especially in winter. It is quite difficult to make it under zoo conditions and it has impact for the health of animals and success of breeding.

Key words:*Cervidae*, roe deer, fallow deer, moose, reindeer, red deer, sika deer, David deer, Timor deer, breeding, diseases, nutrition, keeping

Introduction

Cervidae animals of 8 kinds have been kept in Lithuanian Zoo (Table 1). There are roe deer (*Capreolus capreolus*), moose (*Alces alces*), reindeers (*Rangifer tarandus*), red deer (*Cervus elaphus*), sika deer (*Cervus nippon*), David deer (*Elaphurus davidianus*) and Timor

Table 1. Cervidae Kept in Lithuanian Zoo

Animals kept before or at present	Number of kept animals	Since when kept in the zoo	Bred units	Obtained from freedom	Obtained from zoos or other visitors	Stock of animals in April 2006
Capreolus capreolus	50	1951?	2	45	3	-
Rangifer tarandus	35	1959	17	-	18	4
Elaphurus davidianus	14	1969	4	-	10	6
Cervus dama	17	~1976	8	-	9	6
Alces alces	10	1972 (1938)	-	10	-	-
Cervus elaphus	35	1952 (1938)	30	3	2	-
Cervus nippon	6	1953-55	2	-	4?	-
Cervus timorensis	1	1972	-	-	1	-
Total	**168**		**63**	**58**	**47**	**16**

deer (*Cervus timorensis*). The first animals were got in 1938 (the zoo was stated), there were 3 moose and 1 red deer. However, these animals are not included in the table, as we do not have exact information on them.

During the described period we got most of all roe deer from freedom and most of them were fawns found in the forests by people. Sometimes when poachers shoot mothers their fawns are found. We have got roe deer grown by people. In our zoo only two fawns were born on 05.06.1965 dropped by one doe. They grew up successfully. Adult animals most often were ill with digestive tract diseases. Also traumas, other illnesses have also occurred. Reindeers besides the usual feed get various branches; periodically get fodder produced by *Michael Hassel GmbH* for reindeers.

The average age of reindeers is 4.5; longest age of survival is 21 year

Since 1969 we kept 14 David deer. During the period of 1972-1987 4 fawns were born. 1 fawn loitered after a month, 2 were transferred to other zoo, and 1 lived in our zoo for 20 years. At present we have two pairs of David deer of 4 years. Now there are 5 David deer – 1 male and 3 females 4 years old and 1 newborn calf.

Fallow deer have been kept in the Zoo since approximately 1976. During this period we kept 17 animals out of which 8 were born in our zoo. 7 fallow deer grew up successfully and 1 was born with a liver disease, due to that it loitered after 1 day. The adult deer have suffered from traumas more than once, one animal loitered due to a digestive tract disorder, 1 pneumonia case was registered and one doe loitered of paresis. The average age survived by fallow deer is 9.5 years, maximum 16 years.

In our zoo now are 2 males and 4 females of fallow deer and there are 5 albinos of their.

Since 1972 in the zoo 10 moose were kept, although the first 2 moose were obtained in 1938 when the zoo was established, we do not know their fate. All the moose were received from nature. They have not bred at all.

Most diseases of the moose are digestive tract illnesses.

The problem of moose keeping in zoos has always been topical, as moose seldom survive till old age. The greatest problem is their feeding. The rations formed usually do not ensure the moose good health for a long time. Various zoos, research institutes look for best suitable ration (Claus, Kienzle, Wiesler 1999). *Mazuri* produced combined fodder only for non-breeding animals. By that it is clear that these fodders offer opportunities to keep the animals in captivity, but so far to breed them in captivity would be quite a big problem.

The most successful in the history of Lithuanian Zoo was the breeding of red deer. Out of 35 animals 30 were bred in the zoo. Only three cases when the fawns of red deer loitered are known and 1 animal loitered at the age of 2 years. None often occurring illnesses were recorded.

The maximum of survival of red deer is 21 and 22 years. It is impossible to calculate the average age, as nearly all the animals were transferred to other zoos or various visitors in Lithuania.

No data on the diseases of sika deer has been left.

The only Timor deer had been kept in our zoo since 1972 till 1985. On 05 02 1985 it loitered of pneumonia.

The most often *Cervidae* were ill with digestive tract diseases (56% of all diseases). The cause of that was insufficiently balanced food. Before they were fed with corn or its products, vegetables, hay or grass. They were also fed with dried small branches with leaves, green branches. No specialized fodder was produced for deer in Lithuania and there was no opportunity to bring it from abroad in soviet ages. At present we periodically buy fodder from *Michael Hassel GmbH.* During the latter 6-8 years digestive diseases among *Cervidae* occur rarely.

Other diseases were much rarer: metabolism disorders – 13%, infections – 9%, (often a consequence of traumas), respiratory system disorders – 7%, traumas – 14%.

Material and methods

The material for writing this article has been collected from the zoo animals autopsy acts, case history sheets and other sources. Alas, these data have been accumulated since 1985. Earlier data were episodic. The aim of the article is to review the problems of kept *Cervidae* keeping and breeding in short.

Results and discussion

Lithuanian Zoo was especially successful in breeding red deer. By the experience of the zoo it is clear that no special efforts are necessary for their keeping and breeding. The same can be said about fallow deer and David deer. The zoo comes across many problems when breeding reindeers, as the fawns are born weak and often become ill and loiter. I think the principal problem used to be unbalanced feeding. Although the zoo has kept many roe deer, the adult animals were few and the opportunity to breed them used to occur rarely, as rarely there was an opportunity to form a pair.

Roe deer most often was ill with intestine diseases (~54% of all diseases), metabolism disorders (~30%). Average roe deer survived age is 2.3 years, as most often fawns loiter. Often we get already exhausted fawns. Most roe deer loiters at the age of several months and 2-3 years. Maximum survival of roe deer in the zoo is 7 years.

Totally in our zoo 35 reindeers were kept. Since 1967 in the zoo 17 reindeers were born. We do not know about the fate of 9 fawns, as no data has remained. The remaining 7 fawns lived for 1-2 months and 1 fawn has survived and now is 4 years old already. So the breeding of reindeers is unsuccessful for us, as the fawns loiter. The principal fawn loitering causes are digestion problems (swell, intestine inflammations), although 1 case of congenital birth (harelip) and 1 trauma have also occurred.

Treatments of animals sometimes are unsuccessful, especially in hard cases so it is important to avoid contractions of a disease. Deer must be feed just foods which it is fit for them.

Conclusions

The success of breeding of *Cervidae* largely depends on good balanced feeding. The animal feeding with specialized foods and abundant amount and variety of branches and dried small branches with leaves in winter is of extreme importance.

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http://www.mooseworld.com/

Survival ratio of elephants in polish zoological gardens since the nineteenth century

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Abstract: Since late nineteenth century, Polish Zoological Gardens have kept altogether 52 specimens of both the Indian (Elephans maximus) and African (Loxodonta africana) elephant species. There were nine bulls and thirty cows of the former species and three bulls and ten cows of African elephants. The first Indian elephant female, named *Kaśka* come to Warsaw in 1884 and managed to survive seven years in very bad conditions (the enclosure). At the beginning of the twentieth century, the Poznań zoo kept a pair of Indian elephants including the bull (*Little Cohn*) – originating from the Sarasani Circus in 1913 (Table 1) – and the cow (*Dora*) that came to Poznań in 1910 from the zoo in Koln. In August 1913, the bull became famous for the extraction of its upper incisor without any narcosis. The Warsaw Zoo which – in 1928 – had the largest group of elephants of both species (15 specimens altogether) received the first offspring born in any Polish zoo. It was a female named *Tuzinka* and it was born on April, 16th 1937 to the first breeding pair composed of the bull *Jas* (originating from Frankfurt/a.Main in 1928) and the cow *Kaska II* (that came to Warsaw in 1929 from Rotterdam). After World War II, eight Polish zoos kept single specimens or small groups of elephants. The Zoos in Gdansk and in Katowice mixed the two species in the same enclosures. Besides, Gdansk and Wroclaw zoos received Indian elephant females from some circus. The animals were in poor condition and had serious health problems (primarily with their hooves, but they also had other diseases). The Indian elephant female from the Wrocław zoo named *Ceylon* – born most probably in 1932, which died on the 23rd of April 2000, at the age of 68, was probably the oldest elephant in Poland and one of the oldest elephants living in European zoos. At present, seven African elephants live in Polish zoological gardens: they include a small breeding group (one bull and three cows) kept by the Warsaw Zoo, two females living in the zoo in Katowice and one cow of the Gdańsk Zoo. Six Indian elephants live in five zoological gardens in Poland, including an eight year old male, born at Paris Zoo (Table 1).

Key words: elephant Indian, African, captivity, survival ratio, keeping, longevity, treatment, tusk and molar extraction

Introduction

The keeping of elephants in captivity in European zoological gardens has changed significantly during the last two hundred years. Initially, single individuals were kept in small inner and/or outer enclosures. The floor and the equipment did not consist of natural materials which would most probably negatively influence the living conditions and the longevity of the animals. Slowly, elephants were given enclosures which were more spacious and had a natural surface. Moreover, the treatment, especially of their hooves became more and more professional. At the end of the twentieth century, minimal standards of the enclosure for many animals, including the elephant were established in numerous European countries (mainly present day members od the European Union). The European Elephants Groups started collecting detailed data about the European breeding groups kept in both zoological gardens and in circuses. Local summaries were also recorded in, for instance, the Czech Republic and Slovakia. Data collection from Polish zoological gardens has not yet been completed.

The material and the methods

The details of the two species of elephants kept in Polish zoological gardens in the years 1884-2006 have been analyzed (survival ratio separately for bulls and cows). The data pertaining to 52 specimens, including 39 Indian elephants and 13 African ones, have been collected. For each individual, the data consist of the sex and the name of the animal, the date and place of its birth, the date of its arrival and the place of its origin, the date of its transfer, the cause and the date of its death, its longevity and sometimes the time of its stay in some place other than the given zoo. Moreover, full photographic documentation of a given specimen and (somewtimes) of its enclosure was collected.

Results

Warsaw Zoo kept the highest number of elephants: 15 individuals – 10 Indian and 5 African ones. After the opening of a new enclosure in 2004, five African elephants were transfered to the zoo from wildlife and from captivity. The first Polish elephant kept in a Polish zoo was a female named *Kaśka* – quite an attraction of the collection of exotic animalas at Bagatela Street. It was sold after 7 years of its stay in Warsaw (Fig. 1). Also in Warsaw, on April, 16th 1937, the first and the only elephant was born – a female "Tuzinka" (Fig. 2) (father "Jaś"b. 1929, mother "Kaśka II" b.1918). It was the 26th recorded birth of the Indian elephant in Europe (Schweiger, 1993). The fate of "Tuzinka" is unknown. According to Podhorecki (1959), the elephant was taken away from Warsaw to an unknown place in December 1939, while acc. to Schweiger (1993) it died at the end of World War II, sometime in 1944/45. The two remaining males of the Indian elephant lived almost 50 years: the one named

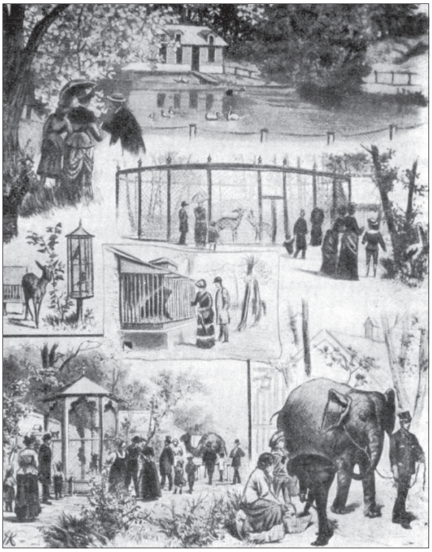

Fig. 1. Zoo Warsaw – first Indian Elephant in Poland lived between 1884-1891

Table 1. Chronological review of Indian Elephants in Polish Zoo since 1885

Lp.	Zoo holder	Sex	House Name	Birth data	Date of arrival	Date of death/departure	Longevity (in Zoo)
1.	Warsaw	f	Kaśka	?	1884 (?)	1891 (sale)	7Y (acc.Podhorodecki 59)
2.	Poznan	F	Nelly	?	1895 (?) German Circus (?)	1907 (? death)	
3.	Poznan	f	Dora	1902	25 May 1910 Koln Zoo	3 March 1941 (shot)	39Y
4.	Poznan	m	Little Cohn	1853 ?	June 1913 Sarasani Circus	16 August 1924 (death)	cr 71Y (?)
5.	Warsaw	f	Kaśka II	cr 1918	June 1928 Frankfurt/aMain	December 1939 (death)	11Y,6M(acc.Podhorodecki
6.	Warsaw	m	Jaś	cr 1926	May 1929 Rotterdam	2 September 1939 (shot)	10Y,4M(acc.Podhorodecki
7.	Warsaw	f	Jenny	cr 1932	Summer 1936	Spring 1939 (sale)	2Y,9M(acc.Podhorodecki)
8.	Warsaw	f	Tuzinka	16 April 1937	16 April 1937 Warsaw	December 1939 (disposal to ?)	2Y,10M(acc.Podhorodecki
9.	Poznan	f	Nekli	1 August 1934 Birma - Rangoon	22 May 1937 Hamburg - Hagenbeck	7 April 1944 (disposal to ?)	9Y,10M
10.	Lodz	f	Magda	cr 1920	1944 (?) Bremmen Zoo (?)	19 September 1960	40Y (14Y)
11.	Warsaw	f	Kaśka III	cr 1946	1 August 1951 Antwerpen	20 July 1956	10Y(5Y)(acc.Podhorodecki
12.	Warsaw	m	Partyzant	cr 1910	5 Sept 1955 South Vietnam	10 September 1956	46Y(1Y)(acc.Podhorodecki
13.	Poznan	f	Kinga	March 1952 India	8 September 1955 Holland	8 October 2003	51Y,7M (48Y,1M)
14.	Wrocław	f	Kama	cr 1944	8 September 1955 Holland	10 April 1981	37 Y (25Y,7M)
15.	Warsaw	m	Rayah	1 March 1949 Sri Lanca	23 April 1952 Holland (420 kg) 23 July 1957 from Rotterdam	9 October 1998 (cardiovascular and tumor)	49Y,7M,8D (41Y,2M,16D)
16.	Warsaw	f	Sonja	cr 1945 Sri Lanca	3 September 1958 Tilburg	31 July 1999	54 Y(40Y,10M,3D)
17.	Opole	f	Taraka	cr 1955 India	19 July 1959 Holland	10 August 1996	41 Y (37, 21D)
18.	Gdansk	f	Bonza	cr 1957 Siam - Bangkok	16 November 1960 Holland	31 October 1976 (toxaemia)	19 Y (15Y,11M,16D)
19.	Katowice	f	Gina	January 1955	8 August 1961 Torino Circus	2 December 1982	27Y,11M,7D
20.	Cracow	f	Kinga	1960 India	April 1963	22 July 2000 (foot, cardiac prob)	40 Y(37Y,3M)
21.	Lodz	f	India	1958 India	April 1963 (355 kg)		
22.	Lodz	f	Magda II	1960 India	April 1963 (305 kg)		
23.	Warsaw	f	Nera	1 April 1962 India	April 1963 (295 kg)	9 Juli 1998	36Y,3M,16D(35Y,2M,21D
24.	Plock	f	Petra	1963	15 September 1964 Holland	30 May 1998 (foot festring)	35Y(33Y,8M,15D)
25.	Katowice	m	Kajtek	June 1964	30 September 1965	10 February 1967 (drowning)	2Y,8M,10D
26.	Katowice	m	Czang	January 1967	11 September 1967 W.Sensen	11 October 1967	9 M,9D (1M)
27.	Gdansk	f	Samanta	1966	21 September 1967 Holland	25 November 1986 (cardiac pr.)	20Y (19Y, 1M,4D)
28.	Katowice	m	Alik	January 1962	4 December 1968 imp.Circus	7 July 1973	11Y,6M,7D
29.	Wroclaw	f	Nora	?	28 April 1976 Czech Ciricus	9 April 1993	(16Y, 11M,11D)
30.	Gdansk	f	Sitakali	1975 India	28 October 1977 van den Brink	8 August1990 (brain cancer)	25 Y (22Y,10M,11D)
31.	Wroclaw	f	Birma	?	8 September 1981 Julinek Circ		
32.	Wroclaw	f	Cejlon	1932 ?	31 August 1985 Julinek Circus	23 April 2000	**68Y !** (14Y,4M)
33.	Gdansk	f	Jawa	1950	15 May 1996 Julinek Circus	12 February 1997 (euthanasia)	47Y (8M,27D)
34.	Cracow	f	Birma	1962	18 September 1996 Jagdeberg		
35.	Gdansk	f	Iky	1952	19 June 1997 Julinek Circus	22 February 2003 (blood circul.)	51 Y (5Y,8 M, 2 D)
36.	Gdansk	f	Darka	1962	19 June 1997 Julinek Circus	14 July 2004 (suddenly death)	42 Y (7Y,26D)
37.	Plock	m	Santosh	15.03.1996 Kopenhagen	24 April 2003	9 Feb 2006 (Bacterial anaerobic infection)	10 Y (3Y)
38.	Plock	m	Thisiam	4.05.1998 Paris	14 October 2002		
39.	Gdansk	f	Niky	1969	February 2006 Althof Circus		

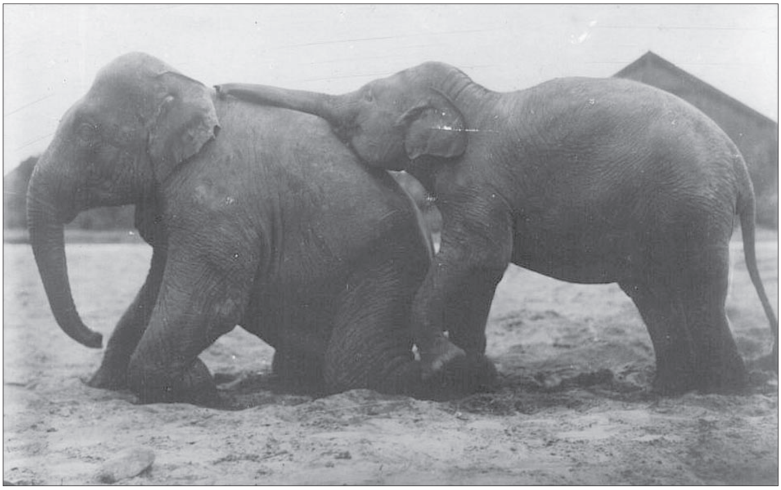

Fig. 2. Zoo Warsaw – first offspring of Indian Elaphant born in 1937 was female "Tuzinka" with their mother "Małgosia II"

Partyzant which had been brought to Warsaw from Southern Vietnam, lived 46 years (b.1910 – Table 1) and the one called *Rayah* which had been transferred from Blijdroorp Zoo lived 49 years 7 months and 8 days (Table 1). The mean of survival ratio for the three bulls was 36 years and 2,5 months; while for the seven cows, it was 19 years and 1,5 month.

Katowice Zoo kept 10 elephants: 4 Indian (including 3 young males) and six African ones (including a mature couple). A grown-up male called "Jaś" was sold at the age of 25 to Howlets (U.K.) breeding group of African elephants of John Aspiral, where it died of a heart attack after the 3,5 years of its stay abroad (on the 23rd of April 1992). Another young male of the Indian elephant – "Kajtek" at the age of 2 years and 8 months drowned himself in the inner water pool (very unusual cause of death for the species). A mature female of the African elephant called Małgosia had to be killed after she had suffered serious, mechanical injuries at the age of 18 years 5 months and 25 days. At the moment the zoo keeps two grown-up females (born in Namibia in 1987) and capable of reproduction (according to the EEG coordinator of the species dr Ameli Terkel; see: Śmiełowski 1999). The mean of survival ratio for three Indian elephant bulls was less than 5 years, but one cow lived 27 years, 11 months and 7 days (Table 1).

Gdańsk-Oliwa Zoo used to keep eight elephants, including some old Indian ones from the Julinek circus

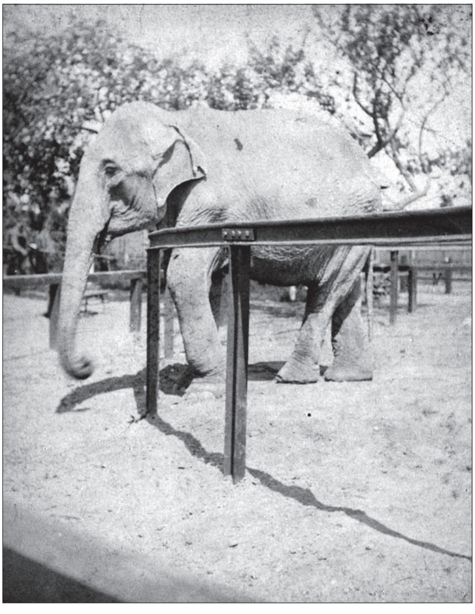

Fig. 3. Zoo Poznań – second Indian Elephant lived in Poznań probably between 1895-1907

(Table 1). For six cows kept here, the mean of survival ratio was 34 years. Nowadays, the zoo has two female elephants from Germany, together with one African elephant named "Mangou" – an aggressive invidual from Rostock and one Indian elephant called "Nicky" which was transferred in February 2006 from the Althof circus (Tables 1 and 2).

Wrocław Zoo after World War II, the Zoo received an old circus elephant, an Indian female called *Ceylon* born probably in 1932 (which died on the 23rd of April 2000, at the age of 68). It was probably one of the oldest European elephants (Table 1). Summing up, after 1945, five elephants were kept here, including one African specimen. The mean of survival ratio for the three cows was 40 years and 7,5 months.

Fig. 4. Zoo Łódź – extraction of molar teeth from female Indian Elephants in 2003 (photo Włodzimierz Stanisławski)

Poznań Zoo kept 5 Indian elephants, including a female "Nelly" – which in the years 1895-1907 was probably the second oldest individual in Poland (Fig. 3). We still lack more detailed information about this animal. In the years 1913-1924, the biggest male elephant "Little Cohn" from the Sarasani circus was kept in Poznań Zoo. It lived probable(?) for 71 years (Table 1). In August 1913, "Little Cohn" underwent an operation during which his left damaged (rotten) tusk was cut. No sedative was used. A simmilar operation was performed in March 1961 when the zoo director, dr Bolesław Witkowski, had to shorten by 10 cm the left tusk (hurting the trunk) of the female "Kinga". This time sedatives were used (Annonymous, 1965). Several years later the operation had to be repeated-and the second tusk was shortened by dr G. Wąsiatycz. Full anaesthesia was applied this time. The mean of survival ratio for three cows was 33 years and 5,5 months.

Łódź Zoo. After World War II the zoo had only one one elephant – an Indian female named "Magda", which had probably been transferred from Bremen in 1944. It was a great attraction for children and family photographs (Ślusarska, 1966). "Magda" died at the age of 40 on September 19th 1960 (Table 1). At present, two females of the Indian elephant "Magda" and "Kinga" from MGK imports are shown to the visitors and regularly weighed (Figure 1). In 2004, one of them had to have the extraction of the left, bottom molar; full sedative was used (Pęcherzewski, 2005 pers.comm.) (Fig. 4 – photo by Włodzimierz Stanisławski)

Płock Zoo keeps three Indian elephants; two young males which were recently born in Europe (Table 1), were transferred to Płock thanks to the EEP programme of this species. The first female "Petra", received at the age of one from the Nederlands, was exceptionally tame. It permitted blind children from the Laski School to have

Table. 2. Chronogical review of African Elephants in Polish Zoos since 1965

Lp.	Zoo holder	Sex	House Name	Birth data	Date of arrival	Date of death/departure	Longevity (in Zoo)
1.	Katowice	f	Małgosia	January 1963	30 Sept 1965 from Holland	23 June 1981 (euthanasia)	18Y,5M,25D
2.	Katowice	m	Jaś	January 1963	18 August 1965 from Holland – Tilburg (van Dijk)	26 October 1988 trade to UK (sale to John Aspinall)	25Y,10M
3.	Wrocław	f	Nell	1970/71 Africa	10 Feb 1974 Dvur Kralove	14 May 1998	(23Y,3M)
4.	Katowice	f	-	January 1982	29 May 1984 Krechting Miller	29 May 1985 Krechting	3Y,4M,27D
5.	Katowice	f	-	January 1982	29 May 1984 Krechting Miller	29 May 1985 Krechting	3Y,4M,27D
6.	Katowice	f	Kinga	Jan 1987 Namibia	19 October 1988 purchase		
7.	Katowice	f	Kizi	Jan 1987 Namibia	19 October 1988 purchase		
8.	Gdańsk	f	Mongu	1975 South Africa	Captured Jan 1979, 1 Aug 1980 Holland (Soest), 2 Nov 1980 Dresden, 10 July 1987 Rostock 24 July 1991 to Gdańsk (gift)		
9.	Warsaw	m	Ninio/Lotek (9906)	30 September 1999 Ramat Gat Zoo Cent	10 July 2003 Tel Aviv, Israel	20 April 2006 transfer to Hungary (Zoo Sosto)	
10.	Warsaw	m	Yoni/Leon (2002)	4 February 2001 Ramat Gat Zoo Cent	10 July 2003 Tel Aviv, Israel		
11.	Warsaw	f	Zula	1997 South Africa	8 August 2004 purchase Africa		
12.	Warsaw	f	Buba	1997 South Africa	8 August 2004 purchase Africa		
13.	Warsaw	f	Fryderyka	1997 South Africa	8 August 2004 purchase Africa		

direct contact with her, cooperation with the blind was also facilitated thanks to the former director of the Zoo – Tadeusz Taworski.

Kraków Zoo kept two females of the Indian elephant. One of them "Kinga" died at the age of 40 due to problems with the circulatory system and the hooves. Kinga was kept together for nearly four years with another female "Birma" in Jagdeburg Zoo (18 September 1996 – Table 1) (Skotnicki, 2001).

Opole Zoo had only one elephant, an Indian female named "Taruka". "Taruka" was born in 1955 in India, and it lived 37 years and 21 days (Table 1), (Anonymus, 1965).

Discussion

The nine Polish Zoological Gardens mentioned above have primarily kept single individuals, and only the Warsaw Zoo used to have some breeding couples of Indian elephants. As a result of the mating experiments only one calf survived in 1937 (Rząśnicki, 1939). After World War II, some unsuccessful mating sessions of a female "Sonja" and a male "Rayah" were observed; no offspring was received. Another prospective breeding couple of African elephants were kept by the Katowice Zoo.

Unfortunately, the female "Małgosia" had to be killed when the doctors were unable to cope with her injuries and serious problems with the trunk. It seems that chances of getting the offspring from the African elephant are now repeated. The Warsaw Zoo has recently imported a group of young animals to a modern enclosure and a new breeding complex has been formed.

The mean of survival ratio of elephants in the Polish zoos is relatively short. The life of the animals is often shortened by problems with their hooves which not infrequently become lethal ones. The hoof problems are almost always aggravated by hard usually concrete surface in inner and outer enclosures (e.g. Poznań). Some of the individuals do not allow for the regular hoof treatment and – as a result – growth of tumourous outgrowths was recorded. Also the skin of many animals had numerous mycotic spots. In Poland, record elephant longevity was 68 years (Wrocław Zoo), yet according to Thai experts the species can live in captivity to be 100 years old (Pat, 2004, pers.comm.). The average of survival ratio for eight Indian elephant bulls was 25,5 years and for twenty one cows 34,7 years.

Other recorded successes include extractions of molars of the Indian elephant with and without sedatives. The last operation held by a Polish team of veterinarians in Łodź Zoo is also worth mentioning here.

Conclusions

At present, stringent requirements defining the minimum standards for several animal species kept in Polish zoos may certainly help in including the zoos into international breeding programmes. On the other hand, numerous young elephants, born thanks to the EEP programmes, need new, modern enclosures, which are understandably quite expensive. Therefore, we are happy to welcome the new construction plans in the Poznań zoo supported by the EU funds. They might open up new possibilities for Poland to receive new breeding groups of elephants. Also a possible transfer of wild elephants from Thailand and India where the surplus animals live in conflict with local population, would give Europe a chance of receiving new genes for the European breeding groups. We should also work on further perfection of breeding methods including the methods of safe nursing propagated by dr H. Schwammer from Vienna Schonbrun as well as the methods of getting the offspring after an artificial insemination. Success of all these methods gives the real hope for the independent breeding of elephant groups in Europe.

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The artery of the head in some mammalian orders

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Abstract: A comparative analysis of the main arterial roads of the head was conducted on 117 species representing 9 orders of the phylum Mammalia. The observations were performed on corrosion casts of the arteries of the head, after injection with plastics. As a result of the conducted comparative analysis it was found that blood to the area of the head and the organs located within the face and the cranial cavity is directed using two specialized arterial roads, for which the maternal vessel is the common carotid artery. The external carotid artery and the maxillary artery constitute the main bipartite arterial road of the head. The internal carotid artery was another road supplying primarily the brain, and in the course of ontogenesis it is connected with the stapedial artery, undergoing extensive modifications. The stapedial artery as a component of the main arterial road of the head in adult animals is found only in some of the investigated rodents. The internal carotid artery in mammals exhibits a wide variability. It is strong and creates anastomosis with the arteries of the base of the brain in Primates, Perissodactyla, Xenarthra, Lagomorpha and only in some Rodentia. The thinner internal carotid artery fuses with the rete mirabile epidurale rostrale in Camelidae. The extracranial segment of the internal carotid artery is completely reduced, in Artiodactyla except for the musk deer and spotted musk deer and in some species from the order Carnivora. The rete mirabile arteriale, the rete mirabile epidurale rostrale in Artiodactyla and the rete mirabile of the maxillary artery in some Carnivora mediate in the transport of blood from the maxillary artery to the vessels of the arterial circle of the brain. It was shown that some traits of the arterial pattern of the head have the characteristics of discriminants useful in taxonomy. The shown variability of the pattern of arteries of the head of the investigated animals is another confirmation of the biological variability of mammals.

Key words: Main arterial roads, the head, Mammalia, comparative analysis

Introduction

The variety of morphologic features of the head, mainly cranium, is created by a group of taxonomical features which are the basis of vertebrate taxonomy. Arteries of the head were also an integral part of the phylogenetic processes of the development and transformations of the head. The aim of this study is a descriptive and comparative characteristic of the main arterial roads of the head in species of nine orders of mammals in view of phylogenesis and taxonomy.

Table 1. Taxonomy and number of investigated species

MAMMALIA			**n** =(? ,?)
	n = (? ,?)	*Mustela putorius* Linnaeus, 1758	2 = (1,1)
Order **Diprotodontia**		Family Phocidae Gray, 1821	
Family Macropodidae		*Halichoerus grypus* (Fabricius, 1791)	1= (1, 0)
Macropus rufus (Desmarest,1822)	1= (1, 0)	*Phoca sibirica* Gmelin, 1788 *	5= (2, 3)
Macropus rufogriseus(Desmarest,1817)	6= (3, 3)	Subfamily Procyoninae Gray, 1825	
Order **Xenarthra**		*Nasua nasua* (Linnaeus, 1766)	2= (1, 1)
Family Bradypodidae		*Procyon lotor* (Linnaeus, 1758)	7= (3, 4)
Chloepus didactylus (Linnaeus,1758)	1= (0, 1)	Family Ursidae G. Fischer, 1817	
Order **Primates**		Subfamily Ailurinae Gray,1843	
Family Cebidae		*Ailurus fulgens* F. G. Cuvier, 1825	1= (0, 1)
Subfamily Atelinae		Subfamily Ursinae G. Fischer,1817	
Ateles paniscus (Linnaeus, 1758)	1= (0, 1)	*Melursus ursinus* (Shaw,1791) *	1= (0, 1)
Family Cercopithecidae		*Ursus arctos* Linnaeus, 1758	2= (1, 1)
Subfamily Cercopithecinae		*Ursus arctos*,Phipps, 1774	1= (1, 0)
Macaca sylvanus (Linnaeus,1758)	1= (1, 0)	FamilyViverridae Gray, 1821	
Papio doguera Pucherman,1856	1= (1, 0)	Podrodzina Paradoxurinae Gray, 1865	
Family Hominidae		*Paradoxurus hermaphroditus* (Pallas, 1777)	1= (1, 0)
Pan troglodytes (Blumenbach, 1775)	3=(1, 2)	SuperfamilyViverrinae Gray, 1821	
Order **Carnivora**		*Viverra zibetha* Linnaeus, 1758 *	1= (0, 1)
Family Canidae		Order **Perissodactyla**	
Canis familiaris (Linnaeus, 1758)	6= (4, 2)	Family Equidae Gray, 1821	
Alopex lagopus (Linnaeus, 1758)	21=(12, 9)	*Equus asinus* Linnaeus, 1758, f. dom.	3= (1, 2)
Nyctereutes procyonides (Gray, 1834)	18=(11, 7)	*Equus burchellii* (Gray,1824)	6= (1, 5)
Vulpes vulpes (Linnaeus, 1758)	26=(19, 7)	*Equus caballus* Linnaeus, 1758	8= (3, 5)
Vulpes vulpes (Linnaeus, 1758)	26=(19, 7)	*Equus przewalskii*	3= (2, 1)
Vulpes zerda (Zimmermann,1780)	2= (2, 0)	*Equus grevyi* Oustalet, 1882	9= (3, 6)
Caracal caracal (Schreber, 1776)	3= (2, 1)	*Tapirrus terestris* (Linnaeus, 1758)	7= (2, 5)
Felis catus Linnaeus, 1758	n = 27	Family Rhinocerotidae Gray, 1821	
Felis chaus Schreber, 1777	2= (1)	*Ceratotherium simum*(Burchel, 1817)	1= (0 1)
Leptailurus serval (Schreber,1776)	2= (1, 1)	Order **Hyracoidae**	
Lynx lynx (Linnaeus, 1758)	4= (2, 2)	Family Procaviidae Thomas, 1892	
Prionailurus bengalensis (Kerr, 792)	1= (1, 0)	*Procavia capensis* (Pallas, 1766)*	3= (1, 2)
Puma concolor (Linnaeus, 1771)	2= (1, 1)	Order **Artiodactyla**	
Subfamily Pantherinae Pocock, 1917		Family Suidae Gray, 1821	
Panthera leo (Linnaeus,1758)	17= (10,7)	Podrodzina Phacochoerinae Gray, 1868	
Panthera onca (Linnaeus, 1758)	1= (1, 0)	*Phacochoerus aethiop.*(Pallas, 1766)	2= (1, 1)
Subfamily Lutrinae Bonaparte, 1838		Rodzina Tayassuidae Palmer, 1897	
Lutra lutra (Linnaeus,1758)	3= (1, 2)	*Pecari tajacu* (Linnaeus, 1758)	5= (1, 4)
Podrodzina Melinae Bonaparte, 1838		Family Hippopotamidae Gray, 1821	
Meles meles (Linnaeus, 1758)	1=(0, 1)	*Hexaprotodon liberiesis* (Morton,1849)	1= (1, 0)
Subfamily Mustelinae G. Fischer, 1817		*Hippopotamus amphibius* Linnaeus, 1758	2= (1,1)
Martes foina (Erxleben, 1777)	3= (1, 2)		
Martes martes (Linnaeus, 1758)	2= (1, 1)	Family Camelidae Gray, 1821	
Camelus bactrianus Linnaeus , 1758	11= (5, 6)	Subfamily Antilopinae Gray,1821	
Camelus dromedaries Linnaeus 1758	2= (2, 0)	*Antidorcas marsupialis* (Zimmermann,1780)	9 = (6, 3)
Lama glama (Linnaeus, 1758)	6= (3, 3)	*Antilope cervicapra*(Linnaeus,1758)	15 = (6, 9)
Lama guanicoe (Müller, 1776)	5= (4, 1)	*Rhynhotragus kirki*(Desmarest, 1816)	5 = (2, 3)

Lama pacos (Linnaeus, 1758)	1= (1, 0)	*Ourebia ourebi*(Zimmermann,1783)*	1 = (1, 0)
Family Giraffidae Gray, 1821		*Saiga tatarica* (Linnaeus, 1758)	3 = (1, 2)
Giraffa camelopardalis (Linnaeus, 1758)	10= (2, 8)	Subfamily Bovinae Gray, 1821	
Family Moschidae Gray, 1821		*Bison bison* (Linnaeus,1758)	4 =(0, 4)
Moschus moschiferus Linnaeus1758*	2= (0, 2)	*Bison bonasus* (Linnaeus, 1758)	11 =(5, 6)
Family Cervidae Goldfuss, 1820		*Bos gruniens* (Linnaeus, 1766)	2 =(1, 1)
Axis axis (Erxleben,1777)	4= (1, 3)	*Bos javanicus* d Alton, 1823	3 =(1, 2)
Axis kuhlii (Müller, 1840)	2= (0, 2)	*Bos taurus* Linnaeus, 1758 f. dom	2 = (1, 1)
Cervus duvaucellii G. Cuvier, 1823	1= (0, 1)	*Bos indicuss* Linnaeus, 1758	7 = (4, 3)
Cervus elaphus Linnaeus, 1758	36=(3, 33)	*Boselaphus tragocamelus* (Pallas 1766)	9 = (3, 6)
Cervus elaphus Canadensis	4= (0, 4)	Taurotragus oryx *(Pallas, 1766)*	7 = (4, 3)
Cervus eldi M.Clelland, 1842 *	2= (2, 0)	*Tragelaphus angsi* Gray, 1849	21= (6, 15)
Cervus nippon hortulorum Swinhoe, 1864	8= (3, 5)	*Tragelaphus spekei* Sclater	12 =(5, 7)
Dama dama (Linnaeus,1758)	19= (4, 15)	*Tragelaphus strepsiceros (*Pallas, 1766)	4 = (1, 3)
Elaphurus davidianus Milne-Edwards, 1866	3 = (0, 3)	Subfamily Caprinae Gray, 1821	
Subfamily Hydropotinae Trouessart, 1898		*Ammotragus lervia* (Pallas, 1777)	9 = (1, 8)
Hydropotes inermis Swinhoe, 1870	2= (0, 2)	*Capra hircus* Linnaeus, 1758 f. dom	43=(4, 39)
Subfamily Muntiacinae Knottnerus – Meyer, 1907		*Ovis ammon*(Linnaeus,1758) f. dom.	31=(20,11)
Muntiacus reevesi (Ogilby, 1839)	5= (1, 4)	*Rupicapra rupicapra* (Linnaeus,1758)	1= (1, 0)
Subfamily Capreolinae Brookes, 1828		Subfamily Cephalophine Gray, 1871	
Alces alces (Linnaeus,1758)	14= (5, 9)	*Cephalopus montic.*(Thunberg, 1789)	1 = (0, 1)
Capreolus capreolus (Linnaeus, 1758)	42=(6, 36)	*Sylivicapra grimmia* (Linnaeus, 1758)	2= (2, 0)
Odocoileus hemionus (Rufinesque, 1817) *	1 = (0, 1)	Subfamily Hippotraginae Brooke, 1876	
Rangifer tarandus (Linnaeus, 1758)	22=(11,11)	*Hippotragus equines* (Desmarest, 1804	2 = (1, 1)
Family Bovidae Gray, 1821 – krętorogie		Subfamily Reduncinae Knottnerus – Maeyer,1907	
Podrodzina Aepycerotinae Gray,1872		*Kobus ellipsiprymmus* (Ogilby, 1833)	3 = (1, 2)
Aepyceros melampus (Lichtenstein,1812)	5 = (4, 1)	Order **Rodentia**	
Subfamily Alcelaphinae Brooke,1876		Family Castoridae Hemprich, 1820	
Alcelaphus buselaphus cokii/cokei (Günther,1884) *	n = 1 (1, 0)	*Castor fiber* Linneaus, 1758	17=(10,7)
Alcelaphus buselaphus caama ((G. Cuvier,1804)	n = 3 (1, 0)		
Family Muridae Illiger**,** 1815		Family Caviidae Gray, 1821	
Subfamily Arvicolinae**,** Gray, 1821		Subfamily Dolichotinae Pocock, 1922	
Ondatra zibethicus (Linnaeus, 1766)	3 = (1, 2)	*Dolichotis patagonium* (Zimmermann, 1780)	12= (5, 7)
Subfamily Murinae Illiger, 1815		Family Hydrochaeridae Gray, 1825	
Rattus norvegicus (Berkenhout, 1769)	5= (2, 3)	*Hydrochaeris hydrochaeris* (Linnaeus, 1766)	
Family Hystricidae G. Fischer, 1817		Family Myocastoridae Ameghino, 1904	
Atherurus africannus Gray, 1842	2= (1, 1)	*Myocastor coypus* (Molina, 1782)	3 = (0, 3)
Hystrix indica *Kerr, 1792*	3 = (1, 2)	Order **Lagomorpha**	

Family Erethizontidae Bonaparte, 1845		Family Leporidae G. Fischer, 1817	
Erethizon dorsatum (Linnaeus, 1758)	3 = (2, 1)	*Lepus europaeus* (Pallas, 1778	n = 14
Family Chinchillidae Bennett, 1833		*Oryctolagus cuniculus* (Linnaeus, 1758)	n = 31
Lagostomus maximus (Desmarest,1817)	3 = (3, 0)		

* Extremely rare species

Material and methods

The study involved 117 species (including domesticated forms) of 9 orders. Alltogether, there were 817 preparations of the arteries of the head.

Animal material was obtained from national ZOOs, animal slaughterhouses and research institutions. A list of investigated species is presented in tab. 1.

We used the taxonomy of animals according to Mammal species of the world (1993). Arteries of the investigated cases were filled with plastics. Plastics were injected with a medical syringe, to the common carotid artery or to the aorta through the left ventricle of the heart. When plastics polymerized, the preparation was subjected to chemical or enzymatic maceration.

Names of the head arteries were identified using the veterinary anatomical terminology (Pilarski 1978 Milart 2002).

Phylogenetic dependences of mammals were compared with information from a study by Shoshani and McKenn (1998).

Results

The characteristic of the arteries of the head was limited to the main arterial road of the head, which is formed by the common carotid artery, the maxillary artery and the external carotid artery. The internal carotid artery, which is also a branch of the common carotid artery, in most of the investigated cases created a separate arterial road, supplying the brain.

All descriptions were confined to the characteristic of the vascular pattern observed in species of mammals belonging to one order, in special cases separate descriptions were prepared for animals of lower taxonomical units.

Order *Diprotodontia*

The common carotid artery extends into the place where the internal carotid artery arises. The external carotid artery gives off: the lingual artery, the submental artery, the caudal auricular branch and the facial artery. The characteristic feature for this order is that the submental artery arises straight from the internal carotid artery. The alveolomandibular branch is a strong branch of the mandible artery. The maxillary artery gives off: the caudal deep temporal artery with the masseteric artery and the buccal artery. In the end the maxillary artery divides into the descending palatine artery and the infraorbital artery. Branches of the infraorbital artery supply labia.

The internal carotid artery penetrates the cranial cavity and forms the arterial circle of the brain and gives off the ophthalamic artery. The orbital arteries are not connected with the maxillary artery.

Order Xenarthra

The common carotid artery bifurcates into the external carotid artery and the internal carotid artery. The external carotid artery gives off the lingual artery, the facial artery and the caudal auricular artery. The maxillary artery gives off the transverse facial artery, the alveolomandibular artery and the caudal deep temporal artery. The infraorbital artery gives off the buccal artery, the rostral deep temporal artery and settled laterally, a strong labial artery.

The internal carotid artery penetrates the cranial cavity where it participates in the formation of the arterial circle of the brain and gives off the internal ophthalamic artery.

Order *Primates*

The common carotid artery bifurcates into equally strong branches, the external carotid artery and the internal carotid artery. The external carotid artery gives off the linguofacial trunk. The caudal auricular artery and the occipital artery arise forming a common trunk. Ending vessels arising from the maxillary artery are: the ascending palatine artery and the infraorbital artery. The internal carotid artery penetrates into the cranial cavity and connects with the arterial circle of the brain and the internal ophthalamic artery. The orbital arteries remains separated from the maxillary artery.

Order *Carnivora*

In the investigated species of families: *Canidae*, *Mustelidae*, *Procyonidae*, *Ursidae* and the common palm civet from *Varridae* arteries of the head were similarly developed.

A common characteristic in the pattern of head arteries in these species was the appearance of branches of the final division of the common carotid artery: the external carotid artery and the internal carotid artery.

In all the investigated cases of family *Felidae* and in the Indian civet of *Viverinae* the extracranial part of the internal carotid artery was obliterated.

The lingual artery and the facial artery in *Carnivora* originated from the external carotid artery. The rete mirabile arteriale of the maxillary artery was found in all the investigated cases of *Felidae* and in the Indian civet of *Viverrinae*.

The internal carotid artery in those species where it is fully developed, penetrates the cranial cavity and extends into the arterial circle of the brain. In these species which have the rete mirabile arteriale of the maxillary artery, the arterial circle of the brain is developed by branches connecting with the intracranial segment of the internal carotid artery.

Family *Phocidae*

An individual feature in head vascularization in *Phocidae* is a lack of the facial artery, the external ophthalmic artery forms the ophthalmic rete mirabile arteriale. The infraorbital artery is the final segment of the arterial circle of brain, its branches function as the labial arteries.

Order *Perissodactyla*

In species of families: *Equidae*, *Tapiridae* and *Rhinocerotidae*, the common carotid artery forks into the internal carotid artery supplying the brain and the external carotid artery initiating the main arterial roads of the head.

The linguo-facial trunk which gives off the lingual artery and the facial artery form a strong branch of the external carotid artery in Equine. The lingual artery and the facial artery originate independently from the external carotid artery in the rhinoceros and the tapir. The caudal auricle artery in all the investigated *Perissodactyla* is the last branch of the external carotid artery before its final division into the superficial temporal artery and the maxillary artery. The maxillary artery gives off the inferior avelomandibular artery, the meningeal artery and alar branches.

The inferior avelomandibular artery is strong and gives off: the deep caudal temporal artery, the buccal artery and the submental artery and also branches to the mandibular gland. The type of the final division of the maxillary artery differs from those described in other animals.

The internal carotid artery has a sinuous course in *Equidae* and in the tapir. Only in the rhinoceros it forms the rostral epidural rete mirable, which takes part in the formation of the arterial circle of the brain. The rostral epidural rete mirable gives off the thin branch connecting it with the maxillary artery.

Order *Hyracoidea*

The external carotid artery and the internal carotid artery are final branches of the common carotid artery. There is no facial artery and the lingual artery originates directly from the external carotid artery. The caudal auricle artery forms the common trunk with the superficial temporal artery.

From the maxillary artery first originates the inferior avelomandibular artery along with the deep caudal temporal artery and the masseteric branch, the next branch is the buccal artery along with the deep caudal temporal artery. The final division of the maxillary artery proceeds according to the constant scheme described in other orders. The internal carotid artery gives off branches forming the arterial circle of the brain in the cranial cavity and also the internal ophthalmic artery.

Order *Artiodactyla*

Descriptions of head arteries in *Artiodactyla* arranged in three suborders: *Suiformes*, *Tylopoda*, *Ruminantiaon* (McKen *et all.* 1997) account for a major number of species and differention of blood vessels.

Suborder *Suiformes*

The common carotid artery extends into the external carotid artery, the internal carotid artery keeps only a short initial segment, because it obliterates. The branch to the rostral epidural rete mirable is a continuation of the obliterated internal carotid artery. The external carotid artery firstly gives off the lingual artery. The facial artery in all the investigated cases of Suiformes is poorly developed and does not reach the labia. The caudal auricular artery is the last branch of the external carotid artery before its final partition.

The superficial temporal artery gives off the transverse facial artery, it determines the transition of the external carotid artery into the maxillary artery. The maxillary artery gives off numerous branches forming three clusters of arteries. First of those is the inferior avelomandibular artery, the medial meningeal artery (which gives off the thin branch to the rostral epidural rete mirable) and the deep caudal temporal (which gives off the masseteric branch).

In Hippopotamus and Peccaries the external ophthalmic artery also gives off branches to the rostral epidural rete mirable and with the buccal artery (which gives off the strong deep caudal temporal artery and the malar artery, which divides into palpebral arteries) create the second cluster of the maxillary artery branches. Vessels of the maxillary artery final partition form the third cluster of the maxillary artery branches.

The suborbital artery, after leaving the suborbital orifice, ramifies into several branches supplying the lateral part of the nose. In Peccaries those branches supply the upper labium.

The greater palatine artery in *Suidae* and *Hippopotamidae* reaches the upper labium region.

The internal carotid artery in the pig gives off the strong occipital artery, the condylar artery and then extends into the branch for the rostral epidural rete mirable. The condylar artery in Suidae and *Hippopotamidae* creates the even caudal epidural rete mirable.

The rostral epidural rete mirable is formed with dense, connected arteries and arranges in the cranial cavity on both sides of the pituitary. This rete, unlike in other *Artiodactyla*, is supplied by branches arising from the segment of the obliterated internal carotid artery. In the cranial cavity another intercranial segment of the internal carotid artery surfaces. This segment connects with the arterial circle of brain.

Suborder *Tylopoda*

The common carotid artery forks into the external carotid artery and the thinner internal carotid artery, which connects with rostral epidural rete mirable.

The external carotid artery gives off: the occipital artery, the lingual artery and a short trunk of the caudal auricular artery and the facial artery. The facial artery does not reach the notch of the facial vessels but bends by the body of mandible and appears on the lateral surface of the mandible.

The superficial temporal artery, the transverse facial artery, the inferior avelomandibular artery and the deep caudal temporal artery arise collectively from the arterial roads of the head. The external ophthalamic and the external ethmoidal arise independently from the maxillary artery. The external ophthalamic gives off branches to the rostral epidural rete mirable, forms the ophthalmic rete mirabile arteriale and extends into the supraorbital artery. The infraorbital artery, which is one of branches of the maxillary artery final partition, gives off the malar artery and supplies the upper labium.

Suborder *Ruminantia*

The common carotid artery extends into the external carotid artery. The extracranial part of the internal carotid artery obliterates (apart from Musk deer and Spotted musk deer). The external carotid artery gives off the occipital artery which consecutively gives off: the ascending pharyngeal artery, the condylar artery (giving off branches to the rostral epidural rete mirable in *Cervidae*, *Girrafidae*, in Eland of *Bovidae*). The condylar artery connects with the odd caudal epidural rete mirable in Bos and Bison.

The lingual artery and the facial artery form a common trunk or arise separately from the external carotid artery. The facial artery reaches the notch of the facial vessels, bends by the body of mandible and appears on the lateral surface of the mandible and gives off the superior labial artery and the inferior labial artery. There is no facial artery in *Caprinae*, Springbuck, Saiga of *Antilopinae*. A poorly pronounced facial artery appears in Blackbuck of *Antilopinae*.

The linguofacial trunk does not occur in the Giraffe and Reindeer. The caudal auricular artery forks into auricular branches and often gives off the meningeal branch. The superficial temporal artery gives off: the transverse facial artery, the rostral auricle artery, the corneal artery and the palpebral artery.

The transverse facial artery is strong in those species with no facial artery: Springbuck, Saiga of *Antilopinae* and in *Carpinae*.

The transverse facial artery in these animals reaches labia. In Krik's dik-dik of *Antilopinae*, the transverse facial artery runs parallel to the facial artery.

Branches of the maxillary artery are numerous and form three clusters of arteries.

The individual feature arises of rostral branches to the rostral epidural rete mirable from the second cluster and penetrates the cranial cavity through the oval orifice (in *Bovinae*, Blue duiker of *Cephalopinae*, in Common waterbuck of *Reduncinae*, Roan antelope of *Hippotraginae*, Cape hartebeest, Cokes hartebeest, White bearded wildebeest of *Alcelaphinae*, Oribi, Springbuck and Saiga of *Antilopinae*).

The even rostral epidural rete mirable is supplied by the rostral branches and the caudal branch for the rostral epidural rete mirable, which arise from the maxillary artery. In some of investigated cases it is also supplied by the thin branch from the condylar artery.

The external ophthalamic artery forms the ophthalmic rete mirabile arteriale and forks into the external ethmoidal artery and the supraorbital artery. In some cases it gives off the rostral branches to the rostral epidural rete mirable.

The supraorbital artery after leaving the supraorbital duct extends into the labio-maxillary artery in the Giraffe, Roe deer and Reindeer of Cervidae.

Order *Rodentia*

The main arterial roads of the head, its course and type of ramification, connections between arteries in rodents show many variations. In *Castoridae*, *Erethizontoidae*, *Muridae* and *Cricetidae* the common carotid artery finally divides into the external carotid artery and the internal carotid artery. In the other investigated species of *Rodentia* the extracranial part the internal carotid artery is reduced.

The caudal auricular artery and the superficial temporal artery originate from the common trunk from the external carotid artery in *Cavidae*, *Hydrochoeridae*, *Dasyproctidae* and *Chinchilllidae*, in the other investigated cases they originate separately.

The stapedial artery is typical of *Muridae* and *Cricetidae*. This artery originates from the internal carotid artery, runs through the stapes in the middle ear, continues its course and takes over functions of the next segment of the main arterial road of the head.

The stapedial artery gives off arteries supplying the orbit and the eyeball, the descending palatine artery and the infraorbital artery.

The internal carotid artery in *Castoridae*, *Erethizontoidae*, *Muridae* and *Cricetidae* penetrates the cranial cave and supplies the arterial circle of the brain. In *Hystricidae*, *Cavidae*, *Hydrochoeridae*, *Chinchillidae* and *Myocastoridae* the extracranial part of the internal carotid artery obliterates. In these species the brain is supplied by the basilar artery succoured by the infraorbital artery, which originates from the maxillary artery. The infraorbital artery is connected with the arterial circle of the brain by the internal ophthalamic artery.

Order *Logomorpha*

The common carotid artery divides into two branches. The external carotid artery gives off: the occipital artery, the short linguofacial trunk and the caudal auricular artery with the superficial temporal artery. The common trunk of the caudal auricular artery and the superficial temporal artery is the place where it divides from the main arterial roads of the head and separates the external carotid artery from the maxillary artery.

The maxillary artery separates the inferior alveolomandibular artery, the internal ophthalamic artery and the buccal artery and divides terminally. In most of the investigated cases the alveolomandibular artery originates from the maxillary artery.

After penetrating the cranial cavity the internal carotid artery ramifies and forms the arterial circle of the brain.

Summary

Comparing results of our research in the analysis of the head arteries in different species of animals some facts may be stated. The head and all organs connected with it are supplied through two main arterial roads of the head, which are formed by branches of the common carotid artery.

The external carotid artery and the maxillary artery form two-partial main roads of the head.

The internal carotid artery is the second road of the head which supplies mainly the brain. This artery during ontogenesis is relevant to the stapedial artery and modifies. The stapedial artery as a part of the main roads of the head occurs in some adult representatives of Rodentia, which was confirmed by Bugge (1974) and Wible (1987). Main vessels of the facial region give off branches forming specialized groups of arteries. The first group: the lingual artery and the facial artery, which in Equidae from Perissodactyla and some of Artiodactyla, forms the linguo-facial trunk (Godynicki 1972, Frackowiak 2003). The second group: the transverse facial artery and the buccal artery, which supplies muscles of the masticatory apparatus. The transverse facial artery in some cases reaches the labial region. The third group: the inferior avelomandibular artery which penetrates the mandibular canal through the mandibular foramen and supplies dental alveoli, then leaves the canal through the mental foramen and branches in the region of upper labium.

This group is connected with other arteries supplying different parts of the head, in the Tapir from Perissodactyla and in Camelidae from Artiodactyla (Godynicki 1972).

The fourth group is the superficial temporal artery which separates the external carotid artery and the maxillary artery. Its branches supplies the regions of the head, the temporal fossa, the forehead and the antlers. The fifth group consists of the external ophthalamic artery, the external ethmoidal artery and the mallar artery, which supply the orbit and the visual organ.

The sixth group: the descending palatine artery, the sphenopalatine artery, the greater palatine artery and the infraorbital artery, supplies the nose, organs of the nasal cavity, in some cases also the region of the upper labium. In some cases of Rodents this group differs from those described above. The internal carotid artery shows variability in Mammals (Bugge 1974, Wible 1987).

This artery is well pronounced and connects with the cerebral basal arteries in Primates, *Perissodactyla*, *Xenarthra*, *Lagomorpha*, and in some cases of *Rodentia*. The internal carotid artery is thin and connects with the rostral epidural rete mirable (Badowi *et all.* 1977, Godynicki 1972, Frackowiak 2003). The extracranial segment of the internal carotid artery is reduced in *Artiodactyla* (apart from Musk deer and Spotted musk deer) and some of *Carnivora.*

The arterial retes mirable: the rostral epidural rete mirable in *Artiodactyla* (Godynicki 1972) and the rete mirable of the maxillary artery in some *Carnivora* (Frackowiak 1989), mediate in the blood flow from the maxillary artery to the arterial circle of the brain. The above mentioned vessels take over functions of the obliterated intercranial segment of the internal carotid artery.

Some features of the head arterial pattern in the investigated cases can be useful in taxonomy (Bugge 1974, Wible 1987).

The rostral epidural rete mirable is characteristic for *Artiodactyla* and it is the certificate of origin, linking this systematic group. A lack of information about the head arterial pattern in Eparctocyona, which is the group of origin for Artiodactyla, makes impossible to arbitrate the hypothesis of its uniformity (Shoshani, McKenna 1998).

Similarities between head arteries in investigated animals are plesiomorphic and do not prove the phylogenetic dependences.

Variability of the head arterial pattern in the investigated animals is another confirmation of biological variety of mammals.

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Some morphometric features in terms of heart vascularisation of the Indian elephant
(*Elephas maximus* Linnaeus, 1758)

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Abstract: In our study we used 2 hearts of the Indian elephant of both sexes. In one case we used the corrosion-cast technique, in another case the heart was dissected and opened through ventricles and atriums. Several measurements were taken, e.g. the width of the ventricle, aorta and pulmonary trunk walls, the length of ventricle walls and internal diameters of main vessels. There are two coronary arteries observed on the corrosion cast, each arising from left and right aortic sinuses. The left coronary artery divides into the paraconal interventricular branch and the circumflex branch. The right coronary artery goes through the coronary groove and terminates on the atrial surface of the heart as the subsinuosal interventricular branch. We considered the symmetrical type of arterial vascularization of the heart in the Indian elephant. We found three veins of the examined cases: the great cardiac vein, the middle cardiac vein and the small cardiac vein. All veins run in grooves of the heart and flow into the coronary sinus.

Key words: coronary arteries, veins, heart, Indian elephant

Introduction

The heart of the Indian elephant is situated in the middle mediastinum with its long axis directed ventrally and caudally. The surface of the heart is marked by grooves indicating its division into four chambers, the atria above forming the base of the heart and the two ventricles below with their distinct apices forming the bifid apex of the heart. Bifurcation of the apex is very unusual and has not been reported in any other species.

Many authors have studied blood vessels of the heart of different species, but there is limited data on the heart in the elephant. Some of them have researched a large number of preparations, which was not possible in the elephant on account of the availability of this species. Blood vessels of the heart form three different combinations of vascularization. There are three main types of arterial vascularization (Adachi 1928). These types show a domination of one coronary artery or symmetry of both coronary arteries. Type I, described as symmetrical, shows an equal development of both coronary arteries, type II is when the right coronary is dominant and type III is when the left coronary artery is dominant. In the midst of type III we distinguish IIIa (when the subsinuosal interventricular branch runs in the subsinuosal interventricular groove) and IIIb (when the paraconal interventricular branch reaches the apex and transverses to the subsinuosal interventricular groove and runs towards the crux of the heart).

Some aspect of the anatomy and histology of the heart in the Indian elephant was described by Mariappa (1986). A set of data considering the anatomy of the Indian and African elephant was included in a dissertation of Güßgen (1988).

In our study we considered some morphological aspects of the heart in the Indian elephant which may broaden present knowledge.

Material and methods

The hearts of two Indian elephants (male and female) were obtained from ZOOs in Poznań and in Płock. The heart of a 51-year old female elephant weighed 19.850 kg (with the epicardium). The heart of a 10-year old male elephant weighed 14 kg.

In one case we used the corrosion-cast technique. We used plastic injected via a cannula to both ventricles.

All vessels apart from the pulmonary trunk and aorta were sealed.

One portion of plastic was colored with a blue pigment and injected to the pulmonary trunk, another portion of plastic was colored with a red pigment and injected to the aorta. Next the heart was left for 24 hrs to polymerize. After a year and a half long period of enzymatic maceration corrosion the cast of coronary arteries and veins was ready.

We used this cast to make observations of patterns of coronary arteries and veins and measurements of diameters of main branches.

In the second case we dissected the heart and opened ventricles and atriums, took measurements of the width of the ventricle, aorta and pulmonary trunk walls, the length of ventricle walls and internal diameters of main vessels and atrioventricular orifices, as well as observed papillary muscles of each ventricle. Afterwards we placed the specimen in a formalin solution.

Results

The heart of the Indian elephant is large and ovoid, the left ventricle is larger than the right ventricle and the left atrium is smaller than the right atrium. The notch of the cardiac apex is deep and separates apices of the ventricles thus giving a bifid apex. On the heart preparation of the female elephant the following measurements were made:

- Thickness of the right ventricle wall – 2.5-3.5 cm
- Thickness of the left ventricle wall – 5 cm
- Length of the left ventricle – 30 cm
- Width of the left ventricle – 24 cm
- Length of the right ventricle – 20 cm
- Width of the right ventricle – 21 cm

- Width of the aortic valve – 9 cm
- Length of the aortic valve – 6 cm
- Thickness of the aortic wall – 2-2.5 cm
- Thickness of the pulmonary trunk wall –1 cm
- Width of the pulmonary trunk valve – 8 cm
- Length of the pulmonary trunk valve – 4 cm
- Internal diameter of the aorta – 8 cm
- Weight of the heart – 14 kg
- Circumference of the right atrioventricular orifice – 23 cm
- Circumference of the left atrioventricular orifice – 25 cm

On the corrosion cast of the female elephant heart the following measurements were made:

- Diameter of the paraconal interventricular branch 12.7 mm
- Diameter of the left circumflex branch 11.4 mm
- Diameter of the subsinuosal interventricular branch 7.1 mm
- Diameter of the great cardiac vein 9.3 mm
- Diameter of the middle cardiac vein 7.4 mm
- Diameter of the small cardiac vein 8.9 mm

There are two coronary arteries on the corrosion cast, each arising from left and right aortic sinuses. The left coronary artery arises from the left aortic sinus and divides into the paraconal interventricular branch and the circumflex branch (Fig. 2).

The paraconal interventricular branch runs towards apices on the auricular surface of the heart, after reaching apices transverses to the atrial surface of the heart.

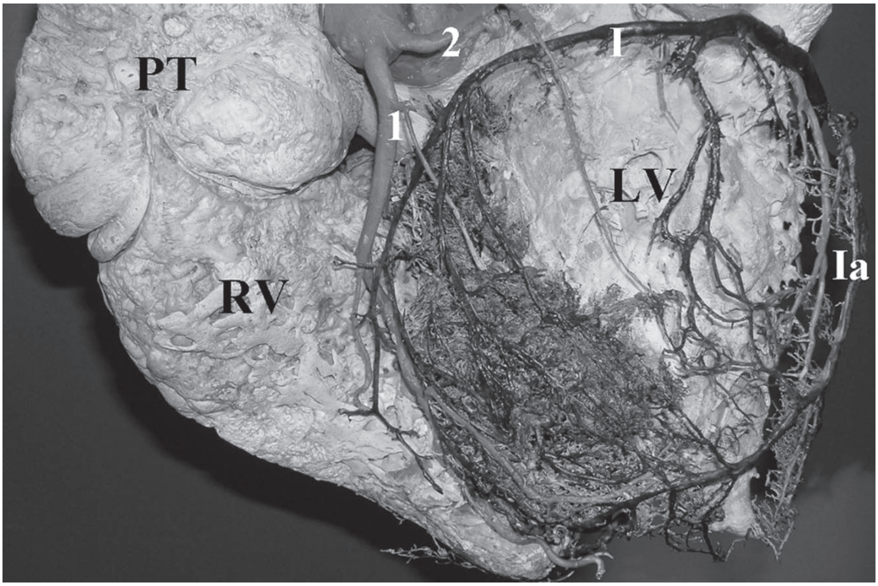

Fig. 1. Anastomoses between the left marginal vein and the great cardiac vein.
PT – pulmonary trunk, LV – left ventricle, RV – right ventricle, 1 – paraconal, interventricular branch, 2 – circumflex branch, I – great cardiac vein, Ia – left marginal vein

The paraconal interventricular branch on its course divides into many branches.

The left circumflex branch runs between the left atrium and the left ventricle. The left circumflex terminates on the atrial surface of the heart before the subsinuosal interventricular groove.

The right coronary artery after dividing from the aorta passes between the right atrium and right ventricle on the auricular and the atrial surfaces of the heart. It goes through the coronary groove and terminates on the atrial surface of the heart as the subsinuosal interventricular branch. The paraconal interventricular branch gives off subbranches on the walls of the left and the right ventricles. Some of small branches originating from the paraconal interventricular branch penetrate the interventricular septum.

We considered the symmetrical type of arterial vascularization of the heart in the Indian elephant.

There are three heart veins in the Indian elephant: the great cardiac vein, the middle cardiac vein and the small cardiac vein. All veins flow into the coronary sinus which is a wide venous duct.

The great cardiac vein commences between apices of the heart and ascends along the paraconal interventricular groove and reaches the coronary groove, then it curves to the atrial surface of the heart and opens into the left extremity of the coronary sinus. This vein is supplied by tributaries from the ventricles. On the auricular surface of the left ventricle the proximal and the marginal branches form anastomose (Fig. 1).

The middle cardiac vein commences between the apices, ascends along the subsinuosal interventricular groove and ends in the coronary sinus near its right extremity. The middle cardiac vein forms anastomoses with the great cardiac vein in the region of the interventricular septum. The small cardiac vein is situated at the

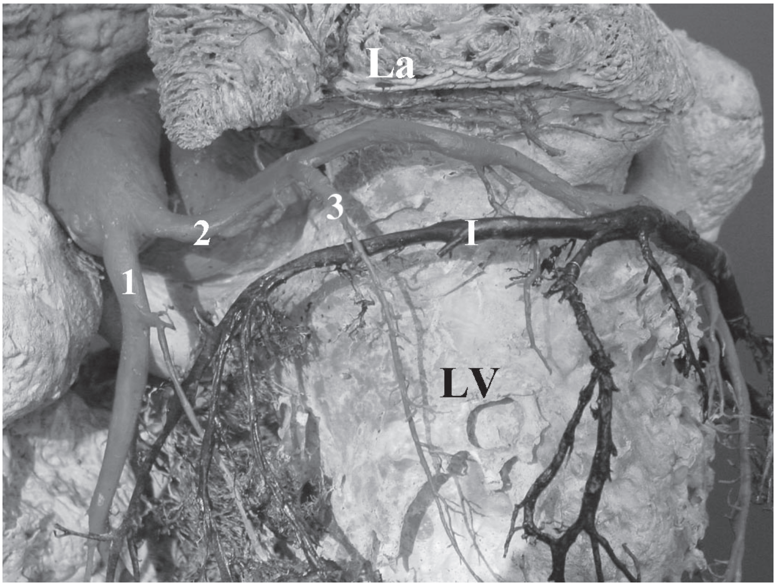

Fig. 2. The left coronary artery.
La – left auricle, LV – left ventricle, 1 – paraconal interventricular branch, 2 – circumflex branch, 3 – proximal branch of the left ventricle, I – great cardiac vein

back of the coronary groove between the right atrium and the right ventricle and it ends in the eighth extremity of the coronary sinus. It receives blood from the auricular surface of the right atrium and the right ventricle. It anastomoses with the middle cardiac vein in the region of the right apex of the heart.

The subepicardial fat covering the base of the heart, filling the interventricular septum and the coronary groove, was 2 cm deep and there were numerous small vessels penetrating it. The fat layer extends over the upper parts of the ventricles.

The right ventricle has a thinner wall than the left. The tabeculare carneae forms two large papillary muscles. Each has several chordae tendinae attached to the septal cusp. The atrioventricular opening between the left ventricular and the left atrium is circular and wider than the opening between the right ventricle and the right atrium.

Trabeculae carneae of both ventricles form papillary muscles. There are two papillary muscles in the left ventricle, one on the internal side of the left ventricular border (length 9 cm, with 6 tendinous chords), second on the internal side of the auricular surface of the left ventricle, which secondarily divides into two muscles (length 9 and 7.5 cm, with 7 and 11 tendinous chords). There are two papillary muscles in the right ventricle, each dividing symmetrically into two muscles, staying in pairs. The pair of muscles on the internal side of right ventricular border (length 9 and 6 cm, with 5 and 4 tendinous chords). The pair of muscles on the interventricular septum in the right ventricle is 10 and 9 cm in length, with 6 and 4 tendinous chords).

Discussion

There is limited data on the morphometric features of the Indian elephant. Burwell (1965) measured the heart of the Indian elephant (adult female), it weighed 19.3 kg, the width was 38cm, the diameter of the aorta wall was 12.5cm, the thickness of the aortic wall was 2.5cm, the width of the aortic valve was 11cm, and the diameter of coronary arteries was 10mm. Our results differed from those of Burwell (1965), because of the age difference of the investigated animals.

Our description of the coronary artery pattern in the Indian elephant is similar to those of Berg (1964) concerning pigs and Hoffman (1975) concerning horses.

The existence of two main coronary arteries: the right coronary artery and the left coronary artery, arising from the right and left aortic sinus, and also their range of supply indicate a symmetrical type of arterial vascularization of the Indian elephants heart. This arrangement was described and named as Type I by Adachi (1928).

Mariappa (1968) observed two coronary arteries arising from the right aortic sinus in an Indian elephant fetus. Both coronary arteries observed by Mariappa (1968) were well developed and vascularized comparative regions of both ventricles.

The main branches of the left coronary artery arise straight from the left aortic sinus without forming a common stem. Bull and Martinis (2002) found a common stem in 26 cases and in 4 cases there was no observation of a trunk formation, concerning dogs. Omachi (2000) affirmed a common stem in 18 out of 25 investigated cases in dogs. Hadžiselimowić (1982) confirmed the occurrence of a common stem in human heart.

The paraconal interventricular branch flows in the interventricular groove on the auricular surface, crossing the bifid apices of the heart and transverses to the interventricular groove of the atrial surface of the heart. Bhargava and Beaver (1969) observed the paraconal interventricular branch transversing from the auricular to the atrial surface of the heart in cattle. Omachi (2000) demonstrated a similar situation in the dog. James (1961), Lippert (1968), Hadžiselimowić (1982) and Kalpana (2003) reported this case in the human heart.

The right coronary artery is a native vessel for the interventricular subsinuosal branch, which terminates this artery on the atrial surface of the heart. The same situation was observed by Hoffman (1975) in and by Berg (1964) in pigs.

Veins of the elephant heart flow into the coronary sinus, which is a common stem for three main veins of the heart. These vessels are: the great cardiac vein, the middle cardiac vein and the small cardiac vein, named by Mariappa (1968) as the left, the middle and the right.

A characteristic feature of the elephant heart is the presence of venal anastomoses, originating mainly from the great and the middle cardiac veins. This was confirmed by Mariappa (1968), who also described arterial anastomoses in the region of the interventricular septum between the paraconal interventricular branch and the subsinuosal interventricular branch in an elephant fetus.

We found two papillary muscles in each ventricle, but in the right ventricle each muscle divided secondarily. Skwarek *et al.* (2005) distinguished 16 types of papillary muscles of the right ventricle, our case classifies as type 8. Skwarek *et al.* (2005) observed type 8 in 3 of 467 investigated cases. In type 8 according to Skwarek *at al.* (2005) only septal and posterior papillary muscles are found. The first classification of papillary muscles of the right ventricle was established by Grochowski (2001), this classification consisted of 14 types excluding type 15 and type 16. Skwarek enlarged that classification by two additional groups, in which he distinguished: the conal papillary muscle and the papillary muscle of the posterior angle of the right ventricle. Bochenek (1993) reported three papillary muscles in the right ventricle and named them the anterior papillary muscle, posterior papillary muscle and septal papillary muscle. In the left ventricle that author found two papillary muscles: the anterior papillary muscle and the posterior papillary muscle. Ranganathan *et al* (1969) described muscles of the left ventricular as the anterolateral papillary muscle and posteromedial papillary muscle, also divided it into groups depending on the type of morphology of muscles. Rantganathan *et al.* (1969) classified papillary muscles of the left ventricle under three broad categories, depending on the nature of attachment to the ventricular wall and the relative length of the body of the papillary muscle that protrude freely into the ventricular cavity. In our case we found the second category, where the papillary muscle with one third of the body protruding freely into the ventricular cavity. Rantganathan *et al.* (1969) also considered the type of arterial supply of the papillary muscles under which the anterolateral papillary muscle receives branches from the interventricular paraconal artery and the marginal branch of the left circumflex. The posteromedial papillary muscle receives a variable supply from the left circumflex artery and branches from the right coronary artery.

Conclusions

1. Some of morphometric features are similar to the literature data.
2. Coronary arteries in the Indian elephant represent a symmetrical type of arterial vascularization.

3. The right coronary artery terminate as the subsinuosal interventricular branch.
4. There are three veins of the heart in the Indian elephant.
5. Veins of the Indian elephant create anastomoses.

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Vascularisation of the giraffe heart
(Giraffa camelopardalis)

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Abstract: The study of the heart vascularization was performed on 3 giraffe hearts using the corrosion-cast technique and injection with colored latex. We observed that the heart is supplied by the left coronary artery and the right coronary artery. The left coronary artery arises from the left aortic sinus, forms a common trunk and consists of two major branches: the paraconal interventricular branch and circumflex branch. The right coronary artery is less developed than the left, it arises from the right aortic sinus and runs behind the pulmonary trunk, passes on the atrial surface of the heart and terminates on the right ventricle wall. We considered the left type of arterial vascularization in the giraffe heart. We found three veins of the examined cases: the great cardiac vein, the middle cardiac vein and the small cardiac vein. All veins run in grooves of the heart (the paraconal interventricular groove – the great cardiac vein, the subsinuosal interventricular groove – the middle cardiac vein and the coronary groove- the small cardiac vein) and flow into the coronary sinus.

Key words: coronary arteries, heart, veins, giraffe

Introduction

The vascularization of the heart is not a permanent feature, it shows some differences even within representatives of one species. It is possible to state the type of arterial vascularization by comparing different preparations. Hence we received the rare heart material from giraffes we decided to analyse the blood vessels of the heart in connection with the arterial and venous pattern. Vascularization of the heart in most domestic animals was already described, but there is still a lack of information about wild animals. Our aim was to describe the vascularization of the giraffe heart in comparison with other representatives of order Artiodactyls.

Material and methods

Hearts of three giraffes (an adult male, an adult female and a female fetus) were obtained from the Zoological Garden of Poznań. In one case we used the corrosion-cast technique. The plastic used was dental plastic Duracryl injected via a cannula to both ventricles. All vessels apart from the pulmonary trunk and the aorta were sealed. One portion of plastic was coloured with a blue pigment and injected to the pulmonary trunk, another portion of plastic was coloured with a red pigment and injected to the aorta. Next the heart was left for 24 hrs to polymerize. The next step was placing the preparation in the macerating bath at the temperature of 36^{O}C. After a year and a half period of enzymatic maceration the corrosion cast of coronary arteries and veins was ready. We used this cast to make observations of patterns of coronary arteries and veins and took measurements of diameters of main branches. In another case we injected vessels of the heart with coloured latex LBS 3060 and preserved the preparation in 36% solution of formalin. After two weeks when the latex congealed, we removed the fat tissue and the epicardium in order to uncover the arteries and the veins of the heart.

Results

The heart of the giraffe is supplied by two coronary arteries arising from aortic sinuses.

The left coronary artery arises from the left aortic sinus and forms a short common trunk (2.85 cm), running between the left auricle and the pulmonary trunk (Fig. 1).

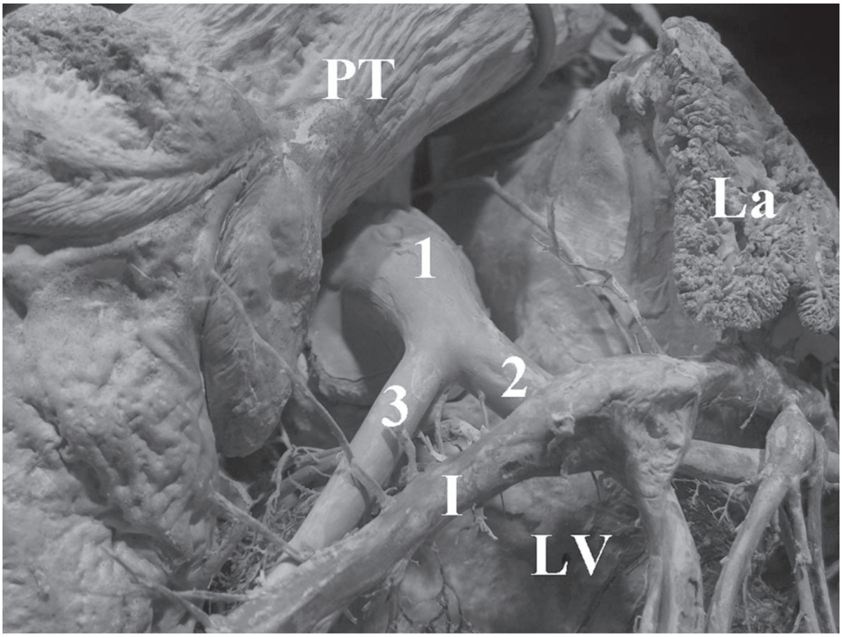

Fig. 1. Common stem of the left coronary artery.
PT – pulmonary trunk, La – left auricle, LV – left ventricle, 1 – left coronary artery, 2 – circumflex branch, 3 – paraconal interventricular branch, I – great cardiac vein

The left coronary artery reaching the coronary groove divides into the paraconal interventricular branch and the left circumflex branch.

The circumflex branch gives off smaller descending branches to the left ventricle wall and to the interventricular septum. It transverses on the atrial surface and terminates in the subsinuosal interventricular groove as the subsinuosal interventricular branch, which runs parallel to the medial cardiac vein.

The left circumflex on its course gives off numerous branches to the left ventricle. The first branch, called the proximal branch of the left ventricle is very well developed, runs parallel to the paraconal interventricular branch and in the half length of the long axis of the heart divides and embraces the apex. The proximal branch of the left ventricle gives off numerous smaller branches, some of which penetrate the heart muscle wall. The final branches of the proximal branch run towards the subsinuosal interventricular groove.

The circumflex branch gives off less developed branches such as the marginal branch, the distal branch of the left ventricle.

The circumflex branch also gives off ascending branches to the left atrium, the first branch is very long and runs towards the sino-atrial node in the interatrial septum. It bifurcates and runs to the left and right atrium.

The paraconal interventricular branch runs in the paraconal interventricular groove and is covered by the great cardiac vein (Fig. 3). Reaching the apex transverses to the atrial surface of the heart and enters the subsinuosal interventricular groove. On its course it gives off numerous smaller branches to the left and right ventricle wall and also penetrates the interventricular septum with small ramifications (10). The first

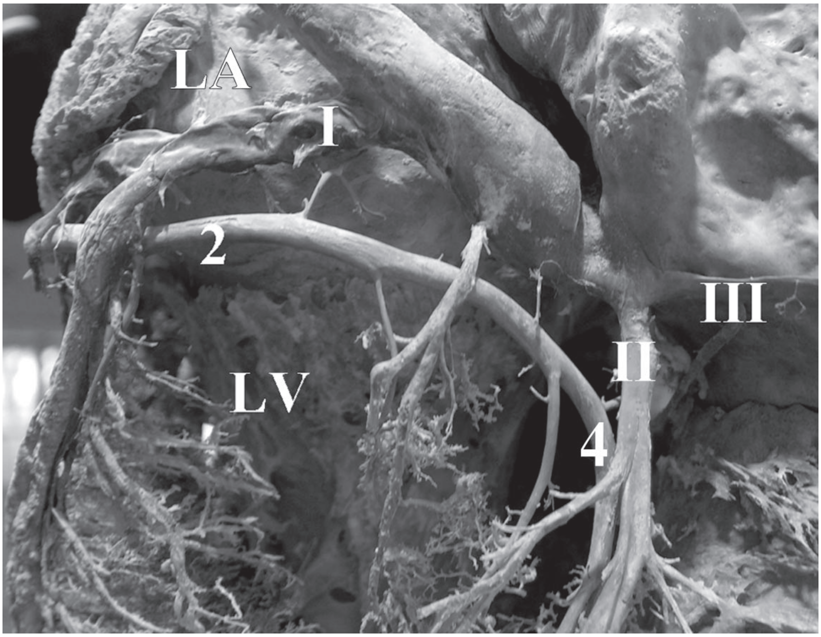

Fig. 2. Coronary sinus.
LA – left atrium, LV – left ventricle, 2 – circumflex branch, 4-subsinuosal interventricular branch, I – great cardiac vein, II – middle cardiac vein, III – small cardiac vein

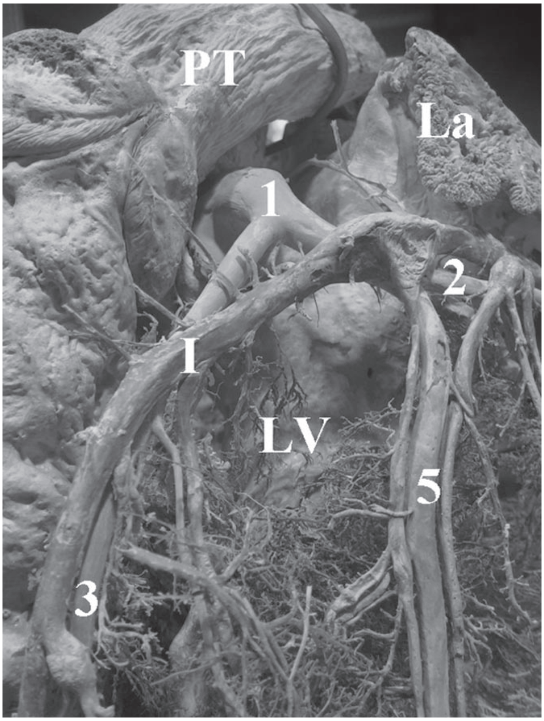

Fig. 3.
PT – pulmonary trunk, La – left auricle, LV – left ventricle, 2 – circumflex branch, 3 – paraconal interventricular branch, 5 – proximal branch of the left ventricle, I – great cardiac vein

branch is well pronounced and usually supplies the atrio-ventricular node. The paraconal interventricular branch supplies the left ventricle wall with two main branches: collateral proximal and collateral distal. The right ventricle wall is also supplied by the branches of the paraconal interventricular branch. On the latex preparation one of the collateral branches to the right ventricle is well pronounced so it supplies most of the auricular surface of the right ventricle. The paraconal interventricular branch gives off the arterial cone branch to the arterial cone, an analogous branch runs from the initial segment of the right coronary artery.

We also found a third well developed branch of the left coronary artery arising from the common trunk between the paraconal interventricular branch and the left circumflex branch, running across the left ventricle known as the angular artery. The angular branch supplied the largest region of the left ventricle in the fetus heart. We observed only small branches of the left coronary artery in the fetus. There was no angular artery on the corrosion cast of the heart in an adult male giraffe, but there were well developed branches of the left circumflex branch: the proximal branch of the left ventricle, the marginal branch of the left ventricle and the distal branch of the left ventricle.

The right coronary artery arises from the right aortic sinus and runs between the pulmonary trunk and the right auricle deep into the coronary groove. The right coronary artery runs towards the crux of the heart, terminates reaching the subsinuosal interventricular groove. On its course it gives off some small branches but it is not as well developed as the left coronary artery. Its first branch, called the arterial cone branch, is best pronounced and with the arterial cone branch originating from the left coronary artery forms the arterial ring.

Veins of the heart accompany the coronary arteries. There are three main veins.

The great cardiac vein covers the area supplied by the left coronary artery, vein branches accompanying arterial branches, so there is the paraconal interventricular branch of the great cardiac vein, which runs parallel to the paraconal interventricular branch of the left coronary artery. The great cardiac vein also gives two branches embracing the proximal branch of the left ventricle and a well developed distal branch running to the left margin of the heart. Branches of the great cardiac vein create anastomoses on the auricular surface of the left ventricle.

The middle cardiac vein runs parallel to the subsinuosal interventricular branch of the left coronary artery in the subsinuosal interventricular groove.

The small cardiac vein is poorly developed and runs in the coronary groove, between the right ventricle and the right atrium.

All veins end in the coronary sinus of the right atrium (Fig. 2).

Discussion

The study on the giraffe blood vessels of the heart showed similarities to other species of orders Artiodactyls and Carnivores. The similarities concerned the type of arising from the aorta and ramification of the blood vessels of the heart. Similarly to other animals in the giraffe heart two coronary arteries were shown. Both coronary arteries arose from the left and the right aortic sinuses (Simoens *et al.* 1978/79; Plarski 1978; Milart 2002; Nickiel *et al.* 1996). Some authors showed differences of ramification of main arterial branches from the aorta (Adachi 1928; Lippert 1967; James 1961; Büll and Martinis 2002) or the presence of just one coronary artery (Sans Coma 1989) in the Syrian hamster and (Lippert 1967) in the human.

The left coronary artery formed a common stem for the paraconal interventricular branch and the circumflex branch, which was also described by Omachi (2000) in dog, (Büll and Martinis 2002) in dog.

The paraconal interventricular branch reaching the apex passed to the atrial surface of the heart and entered the subsinuosal interventricular groove. This case was already described by Bhargava and Beaver (1969) in cattle. The paraconal interventricular branch gave off smaller branches to the right and the left ventricle, also supplying the interventricular septum. The aforementioned branch was covered by the great cardiac vein, this pattern was described as type A1 of venous vascularization (Omachi 2000).

The left circumflex branch arose on the auricular surface and passed to the atrial surface of the heart. On its course it filed the coronary groove and reaching the crux of the heart descended to the subsinuosal interventricular groove as the subsinuosal intervenricular branch. The subsinuosal intervenricular branch was described as a terminating branch of the left coronary artery (Hegazi 1958) in ruminants, (Hadžiselimović 1979) in the wolf, (Omachi 2000) in the dog, and (Büll and Martinis 2002) in the dog. The left circumflex gave off branches supplying the left ventricle. There was the proximal branch of the left ventricle on the auricular surface, the marginal branch on the left margin of the heart and the distal branch of the left ventricle on the atrial surface of the left ventricle. The aforementioned branches were also described by (Hegazi 1958) in ruminants, (Hadžiselimović 1979) in the wolf, (Wilbrand 1988) in the wolf, and (Omachi 2000) in the dog. There were several atrial branches dividing from the left circumflex. The first branch supplied the area of the sino-atrial node. The aforementioned branches were observed by Omachi (2000) in the dog. Beside the left circumflex and the paraconal interventricular branch we found the third branch of the left coronary artery – the angular branch. This branch was already described in the horse by Hoffman (1975).

The right coronary artery was less developed than the left. Lippert (1967) described the case of a total lack of the right coronary artery in the human. The right coronary artery in the giraffe heart passed from the auricular to the atrial surface of the heart and ran towards the crux of the heart, and terminated without reaching the subsinuosal interventricular groove. On its course it gave off smaller branches to the right ventricle wall. The first branch was the strongest and supplied the arterial cone with a similar branch on the other side, dividing from the paraconal interventricular branch. Both of these branches were named the left arterial cone branch and the right arterial cone branch, creating the arterial ring (Hadžiselimović 1982).

An unequal development of the left and the right coronary artery creates different types of arterial vascularization. In our case the left coronary artery was dominant and supplied the largest part of the heart muscle and all the interventricular septum. This pattern is called the left type of arterial vascularization (Hadžiselimović 1982).

Veins of the giraffe heart did not show much difference in comparison to other species. Veins and arteries overlapped. Omachi (2000) established two main types of arteries and veins course: type A (80%), when the great cardiac vein covered the left coronary artery, and type B (20%), when the great cardiac vein is covered by the left coronary artery.

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A case of hydrocephalus in the Przewalski's wild horse

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Abstract: A rare case of hydrocephalus in the Przewalski's wild horse was described. Some morphological observations were taken and corrosion cast of cephalic arteries was made, also bones of cranium were macerated for the purpose of further analysis. On the basis of the morphological analysis and a comparison with literature data we considered hydrocephalus of the internal type. In the examined case we found serious changes in the cephalic arteries pattern. Deformation of particular bones of the cranium was stated.

Key words: hydrocephalus, the Przewalski's wild horse

Introduction

Horses represent 17,50 % cases of malformations in domestic animals. Hydrocephalus in horses is rarely described, it doesn't exceed 3% of all stated malformation of this species (Crowe and Swereczek 1985). Hydrocephalus was already described in warm blood races of Throughbreed (Bowman 1980), in Trotter (Ojala and Ala-Huikku 1992), also in the Konik horses, a representative of Polish primitive horses (Jaworski *et al.* 2002).

Hydrocephalus is characterized by cerebrospinal fluid excess in the cranial cavity. In order to location of the cerebrospinal fluid we may have: hydrocephalus internal (when brain cavities contain cerebrospinal fluid) and hydrocephalus external (when the subarachnoid cave is filled with cerebrospinal fluid). The presence of cerebrospinal fluid excess in brain cavities and subarachnoid cave is a featured of hydrocephalus of the communicational type.

The most popular in animals is hydrocephalus internal two other cases occur rarely (Jubb *at al.* 1993).

The aim of this report is to describe a case of hydrocephalus in the Przewalski's Wild horse.

The Przewalski‘s Wild horse is a wild species of the *Equidae* family which was maintained through for years only in ZOOs and in closed raising. Recently the Przewalski‘s Wild horse was introduced to steppes of Mongolia.

Material and methods

The case concerns a 15 years old mare of the Przewalski‘s Wild horse 1488 ZATOKA MK 0041 (after 555 MARWELL 10 TAMAR and 888 WARSZAWA 11 WISLA) was born 25.06.1986 in the ZOO of Warsaw. The mare was horsed with stallion 1457 SPRUNG MK 0040 (after 749 MARWELL 31 ILKA and 856 SPRINGE 1 SPRINGIA) born on 30.05.1986 in Germany. Both horses were kept in the ZOO in Poznan, the mare from 1987, the stallion from 1989. Previous mare pregnancies proceeded without complications. Foals were born healthy and fully developed. Horsebirth on 21.06.2001 was solved by the Casearean section.

Arteries of the fetus head were filled with colored vinyl superchlorid solution of acetone. The next step was placing the preparation in the macerating bath at the temperature of 36^{O}C. Casts of blood vessels and bones were obtained after the period of maceration.

The imbreed index Fx was estimated on the basis General Studbook of the Przewalski Horse (Kůs 1995). The measurements were made with use of SAS v. 9.13 (2006), INBREED procedure (statistical software).

Results

The fetus head was disproportionately big, it’s circumference was significantly enlarged. The facial part of the skull was narrow and disproportionately small. The skull was soft and prone for to pressure. Cranial bones were thin with defects, filled with fibrous membrane. The zygomatic arch atrophied and orbits were narrowed. The mandible, nasal bones and frontal bones were deformed. In the temporal bone, the pyramid was separated from squamous (Fig. 1).

Hydrocephalus of internal type was found in the fetus.

Two common carotid arteries were found on the preparation. Each ramified in internal carotid artery and external carotid artery. In the cranial cavity, both internal carotid arteries

Fig. 1. A case of hydrocephalus in the Przewalski’ s wild horse. Bones of cranium.
1 – incisive bone, 2 – nasal bone, 3 – mandible bone, 4 – maxilla bone, 5 – frontal bone, 6 – temporal bone, 7 – petrous part (of temporal bone), 8 – parietal bone, 9 – interparietal bone.

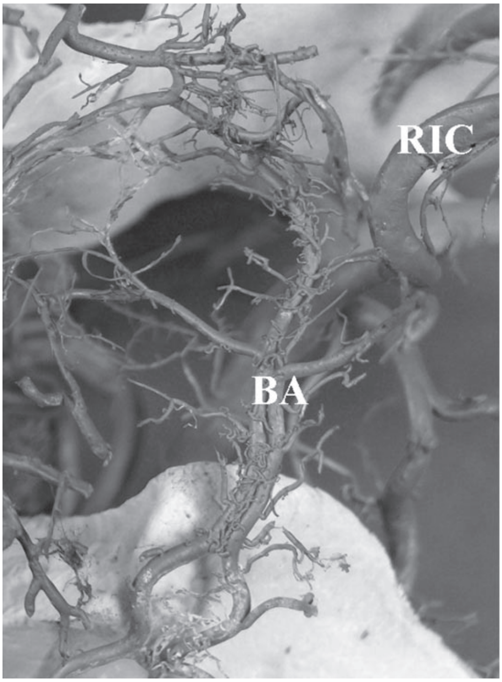

Fig. 2. A case of hydrocephalus in the Przewalski's wild horse. Some of basal brain arteries. BA – basilar artery, RIC – right internal carotid artery

were joined with each other and with the basilar artery. The arterial circle of the brain was not created.

The Przewalski's horse foal estimated imbreed index Fx = 13,48% and aproximetly his father's imbreeds (1457 Sprung) Fx= 13,89% and his mother's (1488 Zatoka) Fx= 25,00 %. Average rate of imbreed for analysed population of 70 horses was 12,58%, stallions were imbredeed at average level of Fx = 8,46 %, mares at average level of Fx = 15,66%. The highest Fx stated at average representative was 48,44%. The foal's parents relationship was at the level of 26,97%.

Discussion

On the basis of morphological features and comparing with literature (Bowman 1980; Crowe and Swereczek 1985; Jaworski *et al.* 2002; Madej *et al.* 2000; Żuliński 1983) the analyzed case of hydrocephalus in Przewalski‘s Wild horse was classified as hydrocephalus internal.

Morphological deformations, which in consequence influence the functioning of internal organs are the effect of malformation in the prenatal period. These malformations in term of their order intensity are described as teratoma or distortion. Reasons of these malformations in order to different authors have genetic or environmental background (Jubb *et al.* 1993).

Congenital hydrocephalus in domestic animals according to some authors is inherited through an autosomal recessive gene, although the role in its origin may be played by viral infections of fetus and dietary factors (Bester *et al.* 1976, Jubb *et al.* 1993).

Cases of hydrocephalus internal in American trotter were reported (Ojala and Ala-Huikku 1992). Authors found 7 cases of hydrocephalus internal within 239 foals of the analyzed stallion. Additional confirmation of the genetic background of hydrocephalus in the described cases was the fact that also sisters of the analyzed stallion were miscarrying foals with hydrocephalus. Congenital hydrocephalus internal in Throughbreed was described by Bowman (1980).

The estimated in our study imbreed index of Przewalski's horse foal with hydrocephalus was Fx = 13,5 %?. This index was similar to obtained in other study described by Jaworski *et al.* (2002) in Konik horse Fx = 15,1%.

The corrosion cast of cerebral arteries enabled observation of vascular system supplying head and brain area. Arteries of the head in investigated foal with hydrocephalus differed from arterial pattern described in Przewalski's Wild horse and other *Equidae* (Frąckowiak and Giejdasz 1998; Frąckowiak 2003).

Described case of hydrocephalus in Przewalski's Wild horse appeared in wild horse species which survived in ZOOs and other closed raisings.

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The morphology of the tongue in the pygmy hippopotamus (*Choeropsis liberiensis*)

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Abstract: The aim of the study was to describe the morphology of the tongue in the pygmy hippopotamus (*Choeropsis liberiensis*) and characterize the distribution and structure of the lingual papillae on the dorsal surface of the tongue. The observations were made on the two tongues of adult pygmy hippopotamus obtained from the ZOO Garden in Poznan. Tongue in pygmy hippopotamus has an elongated body with broad apex. The characteristic structure on the posterior part of the tongue is an elevation of lingual muscle called lingual prominence. On the ventral surface of the apex the fibrillar structure resembling lyssa were found. On the dorsal surface of the tongue 3 types of lingual gustatory papillae: fungiform papillae, vallate papillae and foliate papillae and two types of mechanical papillae i.e. filiform papillae and conical papillae.

Key words: The tongue, morphology, the Pygmy hippopotamus

Introduction

Tongue in the mammals is a organ divided on three main parts i.e. the apex, body and root of the tongue. The important factor influencing on morphology of the tongue is a kind of food or environmental conditions (Thome, 1999, Iwasaki, 2002). Depending on whether the tongue aids in the catching and collecting of food, grinding, turning and swallowing the food morsels, its morphology shows various systematic or species specific traits.

The aim of the study was to describe the morphology of the tongue in the pygmy hippopotamus (*Choeropsis liberiensis*) and to examine the distribution and structure of the lingual papillae on the dorsal surface of the tongue.

Material and methods

The observations were made on the two tongues of pygmy hippopotamus (32 and 34 years old), obtained from the ZOO Garden in Poznan. Both tongues after dissection from the oral cavity were cleaned, measured and photographed. Thereafter the samples were fixed by immersion in the 10 % formaldehyde. For the observations in the light microscope (LM) from apex, body, intermolar prominence and from root of the tongues several tissue several probes in size 1-2 cm were taken and dehydrated in series of the ethanol (70-96%). Then the tissues were embedded in paraplast and the block were cutted in 4-6 um sections. All sections were stained with Masson – Golden method. The results observations of histological slides were documented in Axioscope LM microscope (Zeiss).

Results and Discussion

Tongue of the pygmy hippopotamus has an elongated body with broad apex with extended lateral parts (Fig. 1). The total length of the tongue is ca. 28.5 cm and the width of the tongue is moderate on the apex is 9 cm, on the body of the tongue is 8.2 cm and on the root of the tongue is 10.5 cm. The whole surface of the apex and anterior part of the body of the tongue is slightly undulated. On the dorsal surface of the apex of the tongue the median groove 7-9 cm in length dividing the tongue apex into two symmetrical parts. On the ventral surface of the lingual apex the elongated fibrillar structure resembling lyssa were found.

The characteristic macroscopic structure on the posterior part of the body of the tongue is an elevation of lingual muscle called lingual prominence (Figs. 1, 3). Such a structure, called also intermolar prominence is a typical for some artiodactyls, specially for ruminants and for rodents and play important function during mastication of the herbivorous food (Grandi, 1994, Scala *et al.*, 1995, Kobayashi *et al.*, 1997, Kumar *et al.* 1998, Emura *et al.* 1999, Emura *et al.* 2000, Eerdunchaolu *et al.* 2001, Jackowiak and Godynicki 2005).

On the dorsal surface of the tongue of the pygmy hippopotamus, like in the tongues of the higher orders of the mammals following types of lingual papillae can be distinguished: three types of lingual gustatory papillae: fungiform papillae, vallate papillae and foliate papillae and two types of mechanical papillae i.e. filiform papillae and conical papillae (Thome, 1999). On the apex and anterior body of the tongue we

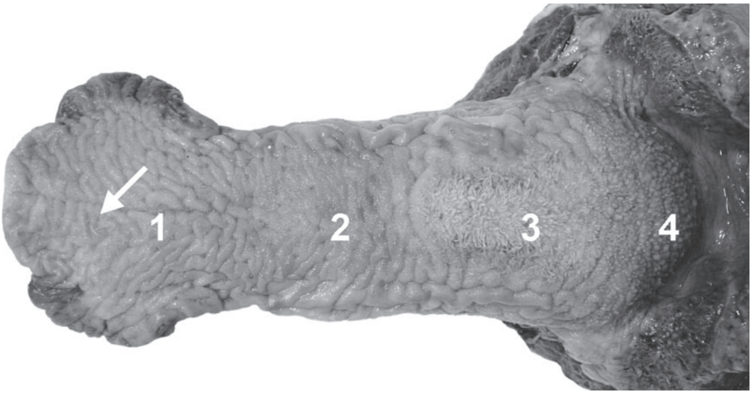

Fig. 1. View on the dorsal surface of the tongue of the pygmy hippopotamus.
1 – Apex of the tongue, 2 – anterior part of the tongue, 3 – lingual prominence on the posterior part of the tongue, 4 – root of the tongue; arrow shows the median groove on the apex

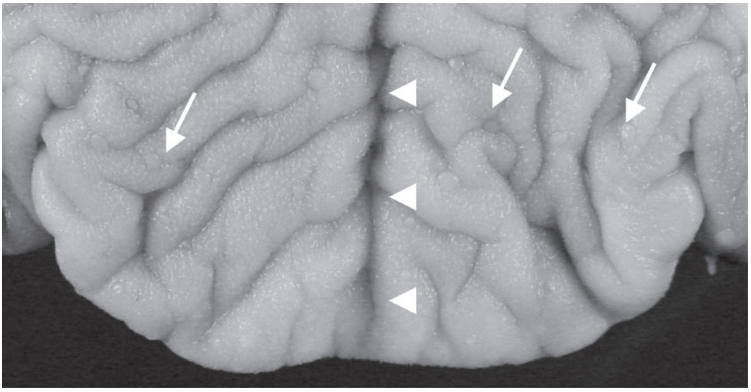

Fig. 2. View on the dorsal surface of the tongue in the pygmy hippopotamus. Arrows – fungiform papillae, arrowheads – median groove

observed macroscopically fungiform papillae, which are regular distributed on the lingual surface and numerous short filiform papillae with a one posterior process (Fig. 2). The total number of rounded fungiform papillae is about 166 . These distributions of both types of papillae are typical for all mammals, but characteristic features in the pygmy hippopotamus are macroscopically visible fungiform papillae.

On the surface of the posterior part of the body i.e. on the lingual prominence only the numerous giant filiform papillae with long keratinized process were observed (Figs. 1, 3). Such a structure of the mechanical papillae on the lingual prominence is a next species-specific feature of pygmy hippopotamus.

As reported the results of the studies in the species belonging to Artiodactyla like cattle, one humped camel, deer, goat, the lingual prominence is covered by short, well keratinized lenticular papillae without processes, which help by grinding the hard and stiff parts of foot (Scala *et al.*, 1995, Kumar *et al.*, 1998, Thome, 1999, Eerdunchaolu *et al.*, 2001). The pygmy hippopotamus food is a general composed from leaves, grasses

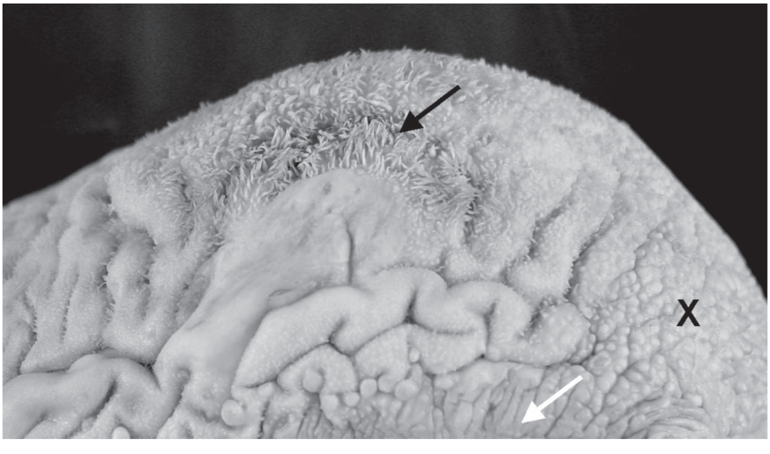

Fig. 3. The lateral view on the lingual prominence and root of the tongue in the pygmy hippopotamus. X – root of the tongue with conical papillae; white arrows – filiform papillae with elongated proccess, black arrows – foliate papilla on the lateral surface of tongue

and tender shoots, so the filiform papillae on the posterior part of the body of the tongue are functional connected with the passage the food to the oesophagus.

Gradually towards the root of the tongue the long filiform papillae disappear and there are gustatory vallate papillae with a flat annular fold and mechanical conical papillae present (Fig. 3). On the flat surface of the posterior part of the root of the tongue covered by palatolaryngeal arch, only the openings of lingual mucous glands are observed.

On both lateral surfaces near posterior part of lingual prominence in the pygmy hippopotamus we have observed symmetrically situated structures similar to foliate papillae (Fig. 3). The left and right foliate papillae are composed of 7-10 leaflets separated by deep fissures. In the Artiodactyla such structures were observed only in Suiformes, but in ruminants, like cattle, goat the foliate papillae on the postero-lateral area of the root of the tongue are absent (Scala *et al.*, 1995, Kumar *et al.*, 1998, Thome H., 1999). The confirmation or the folds of mucosa are really the foliate papillae with a taste buds, or are only the ways of evacuation of the mucous produced by lingual glands situated under the mucosal epithelium, will be clear during our future microscopical studies in the pygmy hippopotamus.

A comparison of the morphology of the tongue in the pygmy hippopotamus and other mammals shows a similarity of macroscopic features of the tongue with that of herbivorous animals. On the other hand, the distribution and microscopical structure of the lingual papillae on the posterior part of the tongue show a species-specific pattern, which is a mosaic of structural featured found previously in animals belonging to Equidae and Suidae

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The morphology of the tongue in the feathertail glider (*Acrobates pygmeus*, Marsupialia)

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Abstract: The aim of the macro- and microscopic studies was to describe the morphology and the three-dimensional structure of the lingual papillae in the fruit nectar and fruit feeder marsupial feathertail glider (*Acrobates pygmeus*). Five tongues of an adult male feathertail glider were used for the study. The microscopic observations were made on the serial histological slides and on specimens under a scanning electron microscope. The elongated tongue of the feathertail glider with a sharpened apex is ca. 10 mm in length. On the dorsal surface of the tongue three types of lingual papillae were distinguished, i.e. filiform papillae, fungiform papillae and vallate papillae. The arrangement, shape and size of filiform papillae and its processes change, depending on the part of the tongue, so that the surface of the tongue resembles a brush adapted to effective ingestion of semi-liquid food. Fungiform papillae are uniformly scattered between filiform papillae only on the anterior and middle part of the lingual body. On the smooth root of the tongue three oval vallate papillae are arranged in the form of a triangle. The structure of the tongue and the arrangement of lingual papillae in the feathertail glider resemble those morphological traits observed in Marsupials and also in small Insectivores.

Key words: tongue, lingual papillae, feathertail glider, marsupials, SEM

Introduction

Marsupials in Australia, due to its geographic isolation, exhibit a wide morphological diversification, depending on the ecological niche they occupy and their anatomical structure, including also the morphology of the alimentary tract, taking features found in the representatives of orders in *Eutheria*. Results of previous microscopic observations showed in marsupials that some characteristics of the structures of the tongue and the mucosa covering it are closely correlated with the diet and similar to those found in large ruminants or carnivores (Kobayashi *et al.* 2003; Kubota *et al.* 1963).

The object of the investigations in this study is the feathertail glider, an arboreal marsupial living in eastern Australia, which is described as the world's smallest gliding mammal (Flannery 1994; Starck 1995). Most species belonging to Burramyids are omnivorous, but in the feathertail glider living in dry sclerophyl forests and woodland, pollen nectar feeding is characteristic (Turner 1984).

Material and methods

The study was conducted on 4 tongues of adult feathertail gliders (*Acrobates pygmeus*), donated by the Zoological Garden in Poznań (Poland). The dissected tongues were cleaned in saline, fixed in 10% neutral formalin and prepared for observations under a scanning electron microscope (SEM). Fixed samples of the tongue were dehydrated in a graded series of ethanol (70%-99.8%) and acetone, and subsequently dried at critical point using CO_2 (Critical Point Dryer K850, EMITECH). All the specimens were mounted on aluminum stubs covered with carbon tabs, sputtered with gold (Sputter Coater S 150B, EDWARDS) and observed under a scanning electron microscope ZEISS 435 VP at the accelerating voltage of 15 kV.

Results and Discussion

The elongated tongue of the feathertail glider (Acrobates pygmeus, Marsupialia) with a sharpened apex is ca. 10 mm in length, while the width of the tongue is constant, amounting to approx. 2.3-2.4 mm. The posterior part of the root of the tongue, with the length of 2 mm, located under the pharyngeal-palatal arch, is narrowed to 0.7 mm (Fig. 2). On the dorsal surface of the tongue three types of lingual papillae were distinguished, i.e. filiform papillae, fungiform papillae and vallate papillae. Scanning electron microscopic observations showed that the arrangement, shape and size of

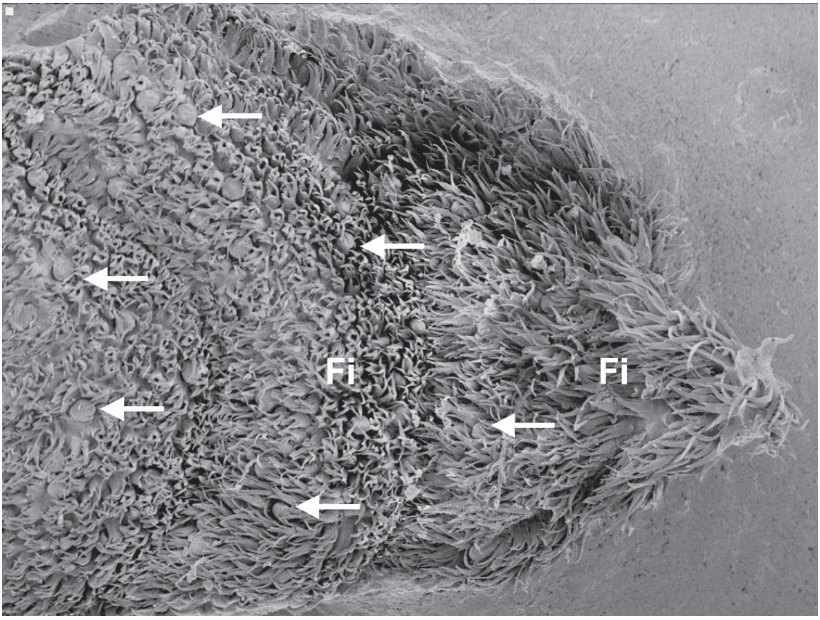

Fig. 1. Scanning electron micrograph of the dorsal surface of the apex of the tongue in the feathertail glider. Fi – filiform papillae, arrows – fungiform papillae, Scale – 200 mm

filiform papillae and its processes change, depending on the part of the tongue, so that the appearance of the surface of the tongue is rough. Filiform papillae are composed of 3-4 flattened keratinized processes with pointed tips, which are tilted towards the back of the tongue. The posterior process is bigger than the 2 or 3 anterior processes. At the margins of the body of the tongue anterior processes of filiform papillae are generally slightly wider and lower than in the papillae located in the medial part of the body of the tongue. In the posterior part of the body of the tongue, in the area of approx. 2 mm in front of the root of the tongue, the arrangement of filiform papillae changes radically, as the papillae with elongated hair-like processes are distributed transversely to the medial line of the tongue. The numerous fungiform papillae are uniformly scattered on the whole surface of the apex and on the anterior and middle part of the lingual body. The second type of gustatory papillae are three oval vallate papillae arranged in the form of a triangle on the smooth root of the tongue.

While comparing the morphology of the tongue of the feathertail glider with other groups of mammals, a similarity was found with the tongues of some species of small Insectivores, i.e. Sorex and Crocidura. The common traits are the short, pointed tip of the tongue and the elongated body of the tongue (Kobayashi *et al.* 1989; Jackowiak *et al.* 2004).

Among marsupials the structure of lingual papillae has been investigated so far in the following species, i.e. in the wombat, wallaby, kangaroo, koala and opossum (Abe *et al.* 2001; Beg and Qayyum 1976; Krause and Cutts 1982; Kobayashi *et al.* 2003; Kubota *et al.* 1963). The distribution of lingual papillae in the feathertail glider resembles the pattern of the lingual papillae in marsupials and also in insectivores. In both

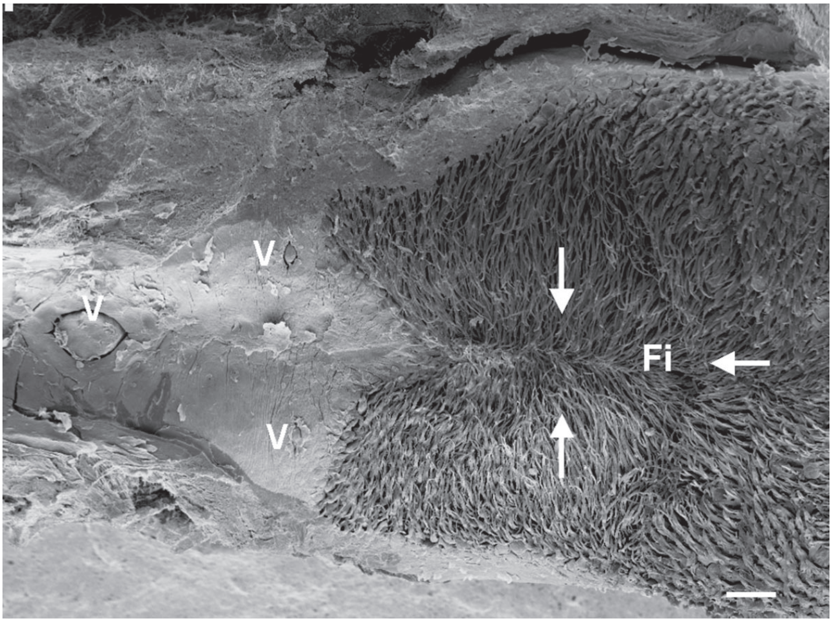

Fig. 2. Scanning electron micrograph of the posterior part of the body and root of the tongue. Fi – filiform papillae, V – vallate papillae on the smooth surface of root of the tongue, arrows show the direction of keratinized processes of the filiform papillae. Scale – 200mm

systematic groups the surface of the lingual mucosa is covered mostly with filiform papillae and has a smooth root of the tongue, devoid of mechanical papillae.

The main food of the feathertail glider is honeydew, eucalyptus pollen, fruit exudates and/or scrapping fruit pulp and feeding on arthropods (Turner 1984). Under keeping conditions of the Zoological Garden artificial feed for feathertail gliders are mixed chopped fruits, honey, lactogen, baby cereal, moths, cicadas and fresh high nectar flowers, if available. In our observations we found a variable distribution of groups of keratinized filiform papillae on the body of the tongue, which is a morphological feature, which make the surface of the lingual mucosa rough and more adhesive. This feature was also observed in the Egyptian Fruit Bat, which suggests that it is a functional adaptation to effective licking.

The three vallate papillae in the feathertail gliders tongue are typical traits for all marsupials and common also for another mammal group – chiropterans (Emura 2002). A large number of fungiform papillae on the lingual body in the feathertail glider, a nocturnal animal, may be connected with the need for enhanced perception of substances in the ingested food.

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The microscopic structure of the lingual papillae n the adult and newborn Egyptian Fruit Bat (*Rousettus aegyptiacus*)

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Abstract: The aim of study was to characterize the distribution of the lingual papillae in the fruit-eating Egyptian Fruit Bat and also to compare the structure of the lingual papillae in the first week after birth with adult specimens. The results show that the distribution of the fungiform papillae and giant filiform papillae on the anterior part of the tongue and vallate papillae on the root of the tongue is similar to the insectivorous Chiropterans. The characteristic features connected with diet of Egyptian Fruit Bat is the pattern of the filiform papillae on the posterior part of the body of the tongue. Our results showed that the development of mechanical papillae is continued after the birth of animals.

Key words: Tongue, gustatory papillae, mechanical papillae, Egyptian Fruit Bat

Introduction

The anatomy of the tongues and the lingual papillae in the Chiropterans were studied mainly in the insectivores species. In available literature the data about microscopical structure of the tongue and lingual papillae are scarce. The previous studies were conducted only in *Pipistrellus nathusii* and *Myotis nattereri* (Wilczyńska *et al.* 2005). Emura et al. (2001) reported on the structure of the tongue in the *Pteropus vampyrus.*)

In the lesser dog-faced fruit bat the structure of the tongue were characterized only in *Cynopterus brachyotis* (Emura *et al.* 2001).

In present study we aimed to characterize the distribution of the lingual papillae in the adult Egyptian Fruit Bat and also to compare the structure the lingual papillae in first week after birth with adult specimens.

Material and methods

Tongues of 4 adult Egyptian Fruit Bat of both sexes were used in the study and on 2 tongues of the newborn bats. The animals were donated by the Zoological Garden in Poznań (Poland).

For the observations under a light microscope (LM) samples of the tongue were fixed in 10% buffered formaldehyde at room temperature. Next the tissues were dehydrated in a series of ethanol with increasing concentrations (70-96%) and embedded in paraplast. The 4 mm thick histological slides were stained by the Masson – Goldner. Morphometric data were obtained using a Multiscan 6.08 computer morphometry system. The figures were documented under an Axioscope 2 plus light microscope (ZEISS).

For observations under a scanning electron microscope (SEM) the samples of fixed tongues were dehydrated in a series of ethanol (70%-99.8%) and acetone, and subsequently dried at critical point using CO_2 (Critical Point Dryer K850, EMITECH). All specimens were mounted on aluminum stubs covered with carbon tabs, sputtered with gold (Sputter Coater S 150B, EDWARDS) and observed under the SEM LEO 435 VP (ZEISS) at the accelerating voltage of 10-15 kV.

Results and discussion

The elongated flat tongue of adult Egyptian Fruit Bat is about 3.5 cm in length and ca. 1 cm in width, whereas in newborn animals the length is ca. 2,5 cm and width 0.8-0.9 cm (Figs 1, 2). On the dorsal surface of the lingual mucosa two types of mechanical papillae and two types of gustatory papillae were observed.

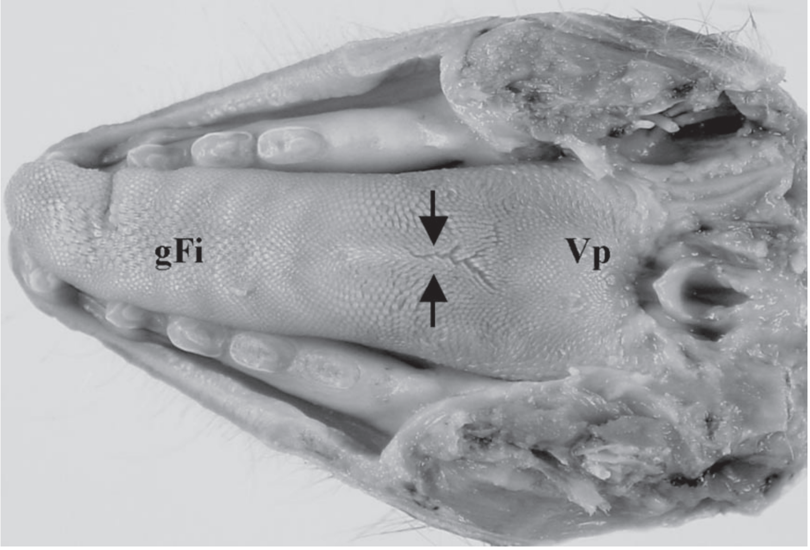

Fig. 1. Tongue in adult Egyptian Fruit Bat; gFi – giant filiform papillae, Fu – fungiform papillae, Vp – vallate papillae; arrows show a direction of processes of filiform papillae on the posterior part of the body of the tongue

The most numerous mechanical papillae on the apex and body of the tongue of Egyptian Fruit Bat are the filiform papillae (Figs.1). On the surface of the apex the and on the anterior part of the body of the tongue in the adult and newborn bats we distinguished small filiform papillae with a one bigger posterior process and several smaller anterior processes and giant filiform papillae with broad posterior process. This kinds of filiform papillae is common in bats and the giant papillae are also called as trifid filiform papillae (Emura *et al.* 2001, Emura 2001, Kobayashi 2001). Second types of mechanical papillae in the Fruit Egyptian Bat are the conical papillae distributed on the lateral margins of the root of the tongue. In the adult animals the filiform papillae, especially giant filiform papillae are well keratinized, this layer is about 27 mm., whereas in newborn bats the keratinization process in the epithelium already starts and on the surface is thin horny layer visible.

The characteristic features of the tongue in Egyptian Fruit bat is a distribution of filiform papillae with long thin processes in posterior part of the body of the tongue. The height of this papillae in adult is about 240 mm. The filiform papillae form a two opposite group, which processes are oriented to the middle line of the tongue. This phenomenon of variable distribution of filiform papillae on the body of the tongue was observed also in the small fruit eater marsupial feather tail glider (Jackowiak and Godynicki, unpublished data). In the newborn bats these papillae are shorter as in adult specimens ca. 180 mm, and their processes start to elongate.

The gustatory papillae in the Egyptian Fruit Bat are represented by numerous round fungiform papillae, ca. 230 mm in height, distributed on the apex and on the lateral margins of the anterior part of the lingual body and on the whole posterior part of the lingual body and three vallate papillae on the root of the tongue. Such distribution of gustatory papillae is typical for all bats (Emura 2001, Kobayashi 2001). In the

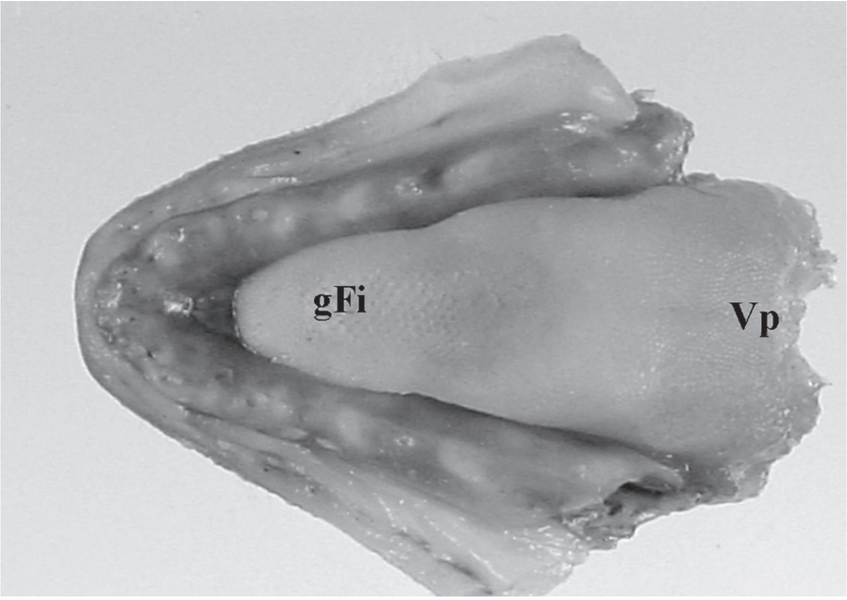

Fig. 2. Tongue in newborn Egyptian Fruit Bat; gFi – band of giant filiform papillae, Vp – vallate papillae

newborn Fruit bat the distribution and structure of the gustatory papillae resembles adult animals. The height gustatory fungiform papillae in newborn is 30 mm. The histological observations showed the differences in the size of these papillae and in height of mucosal epithelium such as in filiform papillae mucosal epithelium in adult is about 83 mm, in newborn is about 33 mm.

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Comparative analysis of skulls of red deer (*Cervus elaphus*) and reindeer (*Rangifer tarandus*)

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Abstract: The aim of investigations was to compare craniometric features of red deer and reindeer. Thirty eight skulls of red deer and twenty skulls of reindeer were measured. Each skull was characterized by fourteen parameters. On the basis of Principal Components Analysis and T-test it was found that these species are different as far as cranial shape is concerned. Despite of the fact that *Rangifer tarandus* has smaller skull in the total length parameter, its nasal cavity is wider comparing to this feature of *Cervus elaphus*. This trait is connected with strongly developed nasal conchas system of reindeer. This may be a result of the adaptation to existing in low temperatures climate. On the basis of the set of craniometric features, the sex dimorphism of reindeer was not observed. In case of red deer the sex dimorphism occurs in proportion with ageing of males. The process of a long term modeling of a skull may be related to strongly developed antlers of older males.

Key words: Cervidae, red deer, reindeer, skull, morphometry

Introduction

Cervidae are an interesting and common research object of various branches of zoology. Many scientific inquires concern their evolution, phylogeny and taxonomy. This subject appeared in the research that has been lately carried out by Cronin (2003), Kuznetsova *et al.* (2005), Pitra *et al.* (2004), Randi *et al.* (1998). On the basis of the above authors' research it can be assumed that the systematic classification of Cervidae has not been exhausted yet. Apart from molecular methods, morphological features of skeleton are used to a significant extant in the taxonomy. Skull is of special importance in the comparative studies of mammals, including Cervidae (Hassanin and Douzery 2003, Meijaard and Groves 2004). Not all metrical parameters of the skull depend exclusively on the genetic background. As has been proved by Wierzbowska (2000) some of the features of viscerocranium are strongly connected with food eaten. The parameters are then dependent on the impact of mandible teeth on maxilla and incisive bone. Such cranial features may bring arbitrariness into the comparative studies. Therefore a proper selections of features is important in this type of investigations.

Although red deer and reindeer belong to the same family of Cervidae, they differ quite considerably as far as morphological features are concerned (Clutton-Brock 1981). The position of red deer in the taxonomy is stable. It belongs to the subfamily Cervinae genus Cervus (Groves and Grubb 1987). Whereas the taxonomic position of reindeer is a subject to frequent changes. According to Pocock (1923) the reindeer is the only member of the subfamily Rangiferinae, genus Rangifer. Several authors (Groves and Grubb 1987, McKenna and Bell 1997, Randi *et al.* 1998,) considered it to be a representative of the subfamily Odocoilenae, genus Rangifer. Wilson and Reeder (1993) classify it as belonging to the subfamily Capreolinae, genus Rangifer. The above authors justify this membership with the specificity of skeleton of metacarpus.

Red deer and reindeer are therefore placed far from one another within the family. In the light of the above conclusion a question arises whether it is possible to show that distance by means of metrical parameters of cranium. Three aims have been set in this paper:

1. Showing similarities and differences of the cranial features of red deer and reindeer.
2. Pointing to those cranial parameters which might prove to be of special importance in taxonomical studies.
3. Showing the sexual dimorphism in these two species in the context of cranial features.

Taking into account the fact that the research was carried out on a relatively small sample its results should be treated as preliminary analyses. They show however certain trends characteristic of deer' skulls.

Material and Methods

Thirty eight skulls of red deer constituted investigated objects. They included 7 males and 31 females. In case of reindeer 20 skulls have been studied and they included 11 males and 9 females.

Each skull was characterized by 14 parameters (Fig. 1 and Fig. 2):

1. Total length: Akrokranion – Prosthion ; AP
2. Short lateral facial length: Entorbitale – Prosthion; EntP
3. Neurocranium length: Akrokranion – Supraorbitale; ASup
4. Lacrimal bone length: Entorbitale – suture of maxilla and lacrimal bone; Lacr
5. Nasal bone lngth: Nasion – Rhinion; NRh
6. Median frontal length: Akrokranion – Nasion; AN
7. Breadth across the nasal cavity; NasBr
8. Facial breadth: breadth across the facial tuberosities; FacBr
9. Least breadth between the orbits: Entorbitale – Entorbitale; EntEnt
10. Greatest breadth between the orbits: Ectorbitale – Ectorbitale; EctEct
11. Greatest neurocranium breadth: Euryon – Euryon; EuEu
12. Breadth between paraoccipital processes; ParaocBr
13. Length of the orbit: EntorbitaleEctorbitale; OrbLen
14. Height of the orbit; OrbHei

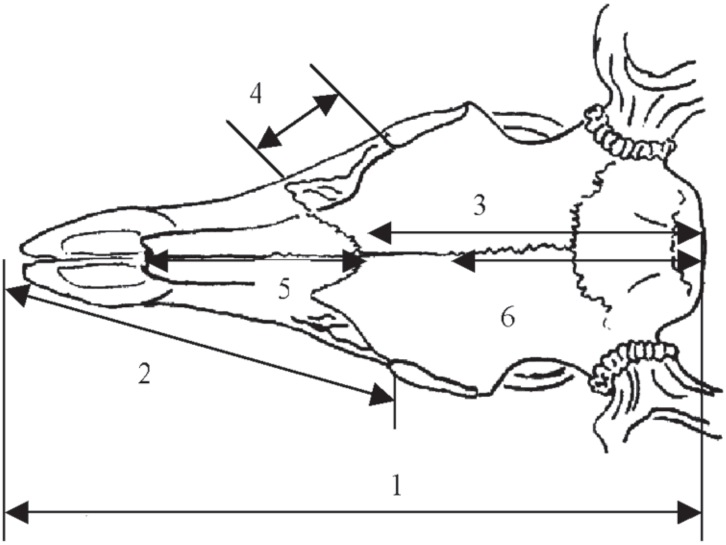

Fig. 1. Some measurements of the skull

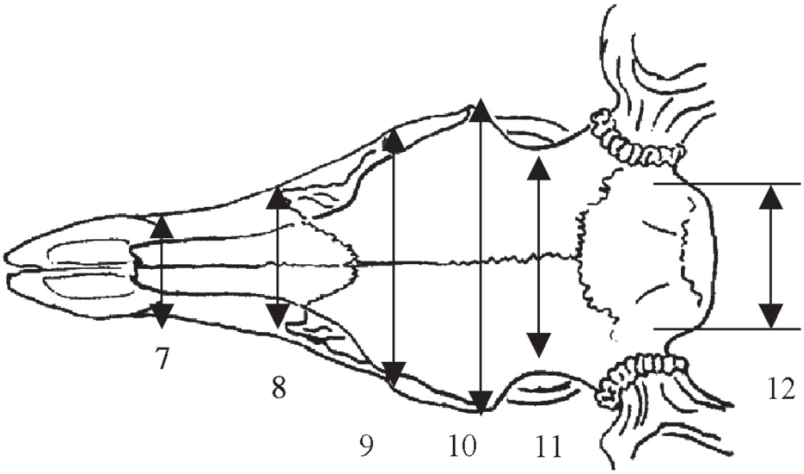

Fig. 2. Some measurements of the skull

From the above set of variables the measurement of the lacrimal bone length (Lacr) was our own idea. Whereas the remaining ones were made according to Driesch's method (1976).

The major stathistical method used in that work was the Principal Component Analysis (Morrison 1990). Its purpose is to describe a given object using a small number of components in relation to a vast set of variables available to the researcher. The primary aim of the PCA is to reduce the set of variables at the smallest possible loss of information. The so-called eigenvalue determines the selection of given linear combinations, i.e. Principal Components.

In the next step the mean values of the cranial parameters were compared with the help of the T-test.

The statistical examination was done in the Statistica 6.0 program.

Results and Discussion

The PCA analysis revealed four components, the eigenvalue of which was bigger than 1.0. These factors jointly explain 70.32 % of the total variability formed by the 14 metric traits (Table 1).

Tab. 1. Selection of Principal Components

Principal Component	Eigenvalue	Percentage of variance	Cumulative percentage of variance
PC 1	5.09	36.33	36.33
PC 2	2.29	16.39	52.72
PC 3	1.45	10.34	63.05
PC 4	1.02	7.26	70.32

After the varimax rotation was performed, each variable was given a load, being the correlation coefficient reflecting the linkage of a variable with a given component. The highest loads (>0.7) in Table 2 are marked in bold.

Tab. 2. Loadings of Principal Components

Variable	PC 1	PC 2
AP	**0.81**	0.23
EntP	0.59	0.29
ASup	0.69	0.19
Lacr	**0.71**	0.09
NRh	**0.87**	0.04
AN	**0.73**	-0.02
NasBr	0.03	**0.72**
FacBr	0.56	0.46
EntEnt	0.11	**0.93**
EctEct	0.22	**0.90**
EuEu	0.14	0.03
ParaocBr	-0.05	0.25
OrbLen	**0.71**	0.04
OrbHei	0.53	-0.09

PC1 is especially linked with five traits out of fourteen (Table 2). All these parameters express the length of the skull in its different regions. So the PC1 is the length factor.

PC 2 defines mostly the breadth between the orbits: EctEct, EntEnt and the breadth across the nasal cavity NasBr. This is a breadth factor then. The PC1 and PC2 explain together about 53 % of the observed variance (Fig. 3).

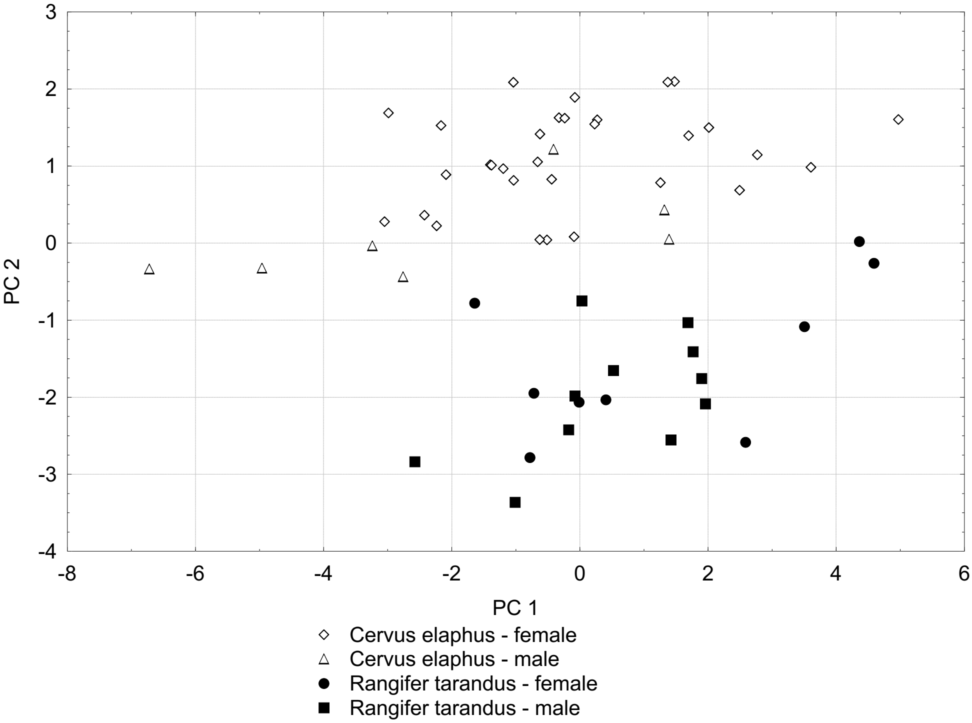

Fig. 3. Plot of Principal Components

The above plot proves that the skulls of red deer and reindeer are metrically different because the polygons of marks do not overlap. However PC 2 seems to be more important in differentiating between these two species. A proper conclusion to make then is that the only differentiating factors are parameters concerning the breadth of skulls. As far as sexual dimorphism is concerned it is observable only in red deer. However young stags do not differ from hinds with metrical features of skull. It is only older stags that moved to the left on the plot. This very fact seems to be connected with stronger development of antlers in older stags. A skull that carries big antlers has to be more massive. Therefore the process of modeling the skull in a postnatal period lasts quite long in a red deer. The skulls of stags and hinds in reindeer are mixed up. Sexual dimorphism does not manifest. The reason for this might be that both stags and hinds have antlers. Merino et al. (2005) have reached similar conclusions studying a few species of Cervidae. The authors claimed that there are no differences in the shape of skull between males and females apart from antlers.

The next stage of the analysis was to compare mean values of skull parameters in red deer and reindeer with the help of the T test (Table 3).

T test confirmed the PCA conclusions which state that red deer surpass reindeer with the length features of the skull. However reindeer surpass red deer with breadth features of the skull. The research carried out by Meijaard and Groves (2004) proves our observations. They showed that Cervus elaphus is craniometrically distinct group, primarily because of high values for length of many features of the skull. The skull

Tab. 3. T test – comparing of cranial parameters between Cervus elaphus and Rangifer tarandus

Variable	Mean value (mm)of *R. tarandus*	Mean value (mm)of *C. elaphus*	Significance level
AP	329.10	347.45	*
EntP	190.75	196.03	ns
ASup	121.75	132.45	**
Lacr	52.80	57.47	**
NRh	100.20	118.13	***
AN	160.10	172.60	**
NasBr	63.10	53.97	***
FacBr	97.60	105.24	*
EntEnt	122.55	110.10	***
EctEct	147.60	139.24	*
EuEu	91.50	90.24	ns
ParaocBr	93.10	86.89	**
OrbLen	44.45	47.50	**
OrbHei	44.60	47.79	***

* p = 0.05
** p = 0.01
*** p = 0.001
ns - not significant

of red deer is slenderer than skull of reindeer. Especially nasal cavity is bigger in reindeer. It is considerably related to the strong development of nasal conchas. More complex nasal cavity and bigger conchas are adaptative features. They allow the animals to adapt to the cold air of polar and subpolar climate in which reindeer lives. It was also observed that orbits are pushed more to the sides in reindeer. Reindeer has also a broader area of the neck (ParaocBr). Features such as the short lateral facial length and the breadth of neurocranium do not seem to be valuable in the comparative metrical analyses of those two species. The mean value of these parameters do not differ significantly in this analyzed groups.

Conclusions

1. Some of the cranial features are characterized by a high species specificity in the analyzed Cervidae.
2. Among the cranial metrical features the parameters connected with the development of the nasal cavity and shaping of orbits are of special importance in the systematical classification.
3. On the basis of cranial measurements the sexual dimorphism has not been found in Rangifer tarandus.

4. In skulls of Cervus elaphus the sexual dimorphism appears in relation to the aging process of stags. Such a pattern of modeling the cranium may be related to a stronger development of antlers in older stags.

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