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Derby eland (*Taurotragus derbianus*) in captivity: studbook analyses

Bachelor Thesis

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Photo: Markéta Švejcarová, 2014

Declaration

I declare that this bachelor thesis entitled "Derby eland (*Taurotragus derbianus*) in captivity: studbook analyses" is my own work and all the sources have been quoted and acknowledged in References.

In Prague: 24.4. 2014

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Markéta Švejcarová

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Finally yet importantly, I am dearly grateful to managers and staff of Bandia and Fathala wildlife reserves and Derbianus CSAW for allowing me to observe Western Derby eland in Senegal. Personal experiences are irreplaceable and helped me a lot with the thesis.

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Abstract

Derby eland (*Taurotragus derbianus*) in captivity: studbook analyses

Population management is the basis of present conservation breeding programs. Many endangered mammalian species are kept in small populations in captivity or semi-captivity. Because the size of population affects significantly the vulnerability and sustainability in general, it is necessary for the management to be led precisely . One of the tools for the conservation breeding is population management software. In this study (1) identical data for *T. d. derbianus* were compared in two versions of software: PM2000 and PMx; (2) data of two subspecies of Derby eland (*T. d. derbianus* and *T. d. gigas*) were processed in PMx and (3) out of the created projections, there was compiled an estimation of their sustainability. Results from the software were often distinctive, mostly due to new used formulas. Results of the subspecies comparison show the impact of founders' number at the beginning of the breeding. Projections showed better future possibility for the Western Derby eland semi-captive population, but both Western and Eastern subspecies requires new founders to assure their sustainability.

Key words: population management, genetics, demography, PMx, wildlife, pedigree

Abstrakt

Analýza plemenných knih antilopy Derbyho (*Taurotragus derbianus*)

Řízení populací je základem současných záchranných chovů. Chov mnoha ohrožených druhů savců je realizován v podmínkách zajetí či polo-zajetí a v nízkém počtu jedinců. Vzhledem k tomu, že velikost populace významně ovlivňuje všeobecnou zranitelnost a udržitelnost populace, je nezbytné, aby byl management chovu veden precizně. Jedním z nástrojů pro řízení záchranných chovů je použití softwarů pro populační management. V této práci byla porovnána (1) identická data *pro T. d. derbianus* ve dvou verzích softwaru: PM2000 a PMx; dále (2) data dvou poddruhů antilopy Derbyho (*T. d. derbianus a T. d. gigas*) v PMx a (3) z vytvořených projekcí byla hodnocena udržitelnost obou chovů do budoucna. Výsledky ze dvou verzí softwaru se často lišily, především kvůli užití různých vzorců k výpočtům. Výsledky mezi oběma poddruhy ukazují na vliv počtu zakladatelů populace. Projekce ukazují na lepší budoucí vývoj v populaci západního poddruhu antilopy Derbyho, nicméně západní i východní poddruh by pro trvalou udržitelnost potřebovali přidání nových zakladatelů.

Klíčová slova: management populací, genetika, demografie, PMx, rodokmen, kopytníci

Content

List of figures and graphs

List of the contractions used in the thesis

ARKS	Animal Record Keeping System
AZA	Association of Zoos and Aquariums
FGE	Founder Genome Equivalents
ISIS	International Species Information System
IUCN	International Union for Conservation of Nature
MedARKS	Medical Animal Records Keeping System
REGASP	Regional Animal Species Collection Plan
SNDSZP	San Diego Zoo's Safari Park
SPARKS	Single Population Analysis & Records Keeping System
USA	United States of America
WAZA	World Association of Zoos and Aquariums
ZIMS	Zoological Information Management System

1 Introduction

The largest antelope in the world is the Lord Derby's Eland, *Taurotragus* (event. *Tragelaphus*) *derbianus* (Dorst and Dandelot, 1972; East, 1999; Kingdon et al., 2013). There are two subspecies with different area of distribution. The Western Derby eland (*Taurotragus derbianus derbianus*) can be only found in Senegal, while the Eastern giant eland (*Taurotragus derbianus gigas*) is extended through several central and eastern African countries.

The Western Derby eland is classified as "Critically endangered" in the Red List of IUCN and the population trend is "decreasing" (IUCN, 2008). According to the last research there were about 170 individuals left in the wild, in the national park Niokolo Koba in Senegal (Renaud et al., 2006). Less than 100 elands are located in two wildlife reserves in Senegal, Bandia and Fathala. Main threats for Western Derby eland in the national park are poaching, livestock grazing, habitat loss and degradation. In the reserves, they are protected, but there can be genetic related risks such as inbreeding depression or bottleneck effect (Brandlová et al., 2013). Without present population management the species is heading to the extinction.

The conservation program started in 2000 with nine animals captured from the wild. Unfortunately, three females died soon and the semi-captive population was established with only six founders, five females and one male. The conservation is running in situ, first in Bandia reserve and later also in Fathala reserve, both in Senegal. Today's population includes over 90 animals, separated in several herds (Antonínová et al., 2004; Antonínová et al., 2006; Brandlová et al., 2013).

Although the first studbook was released in 2008, pedigree data were kept since the beginning and the pedigree is full (except one generation born in 2003). It is very important, because studbooks are a key to successful population management. Using population management software as PM2000 and PMx allows the user to predict the results of any changes in the population structure and its future development (Kolackova et al., 2011; Lacy et al., 2012).

2 Bibliographic research

2.1 Derby eland

Derby eland is a species of African antelope, which was first described in 1847 by Dr. John Edward Gray as *Boselaphus derbianus*. The description was made based on some body parts (skins, horns) brought from West Africa to England. This species is often called also Lord Derby‘s eland, named after 13th Earl of Derby, Edward Smith-Stanley who funded an exploration of African fauna (Bro-Jorgensen, 1997; Kingdon et al., 2013). Taxonomically belongs to Cetartiodactyla order, family of Bovidae and to genus *Tragelaphus* (Matthee and Davis, 2001; IUCN, 2008; Kingdon et al., 2013) or by other authors (including this thesis) to genus *Taurotragus* (Antonínová et al., 2008; Rubes et al., 2008; Groves and Grubb, 2011). There are two subspecies of this antelope, the Eastern giant eland (Heuglin, 1863) and the Western Derby eland (Gray, 1847). The subspecies of Eastern giant eland is substantially more numerous and it is led with status "least concern" in the IUCN Red list. The western subspecies is listed on IUCN as "critically endangered" from 2008, population trend is classified as "decreasing" (IUCN, 2008).

Although Western Derby eland was few decades ago expanded through several western African countries (see Figure 1), today it cannot be found nowhere else than in Senegal (Brandlová et al., 2013). Unlike the Eastern giant eland, it is not bred in any zoological garden in the world (ZIMS, 2014). Last antelopes in the nature live in Niokolo Koba national park; their numbers are estimated to be about 100 - 170 heads (Hájek and Verner, 2000; Renaud et al., 2006). The conservation program runs in Senegal through cooperation between Senegalese and Czech experts since 2000, when there were captured elands from the wild and there was established breeding in captivity. The founders of a new population were those five females and one male transferred to the Bandia reserve, some of them not adult at that time. Currently there are more than ninety antelopes divided into a few herds in two natural reserves. From the beginning, the pedigree is kept very accurate with records of parents of each animal, allowing high level of population management. The only exception is from 2003, mothers of animals born that year are unknown (Antonínová et al., 2004; Brandlová et al., 2013; Koláčková et al., 2011).

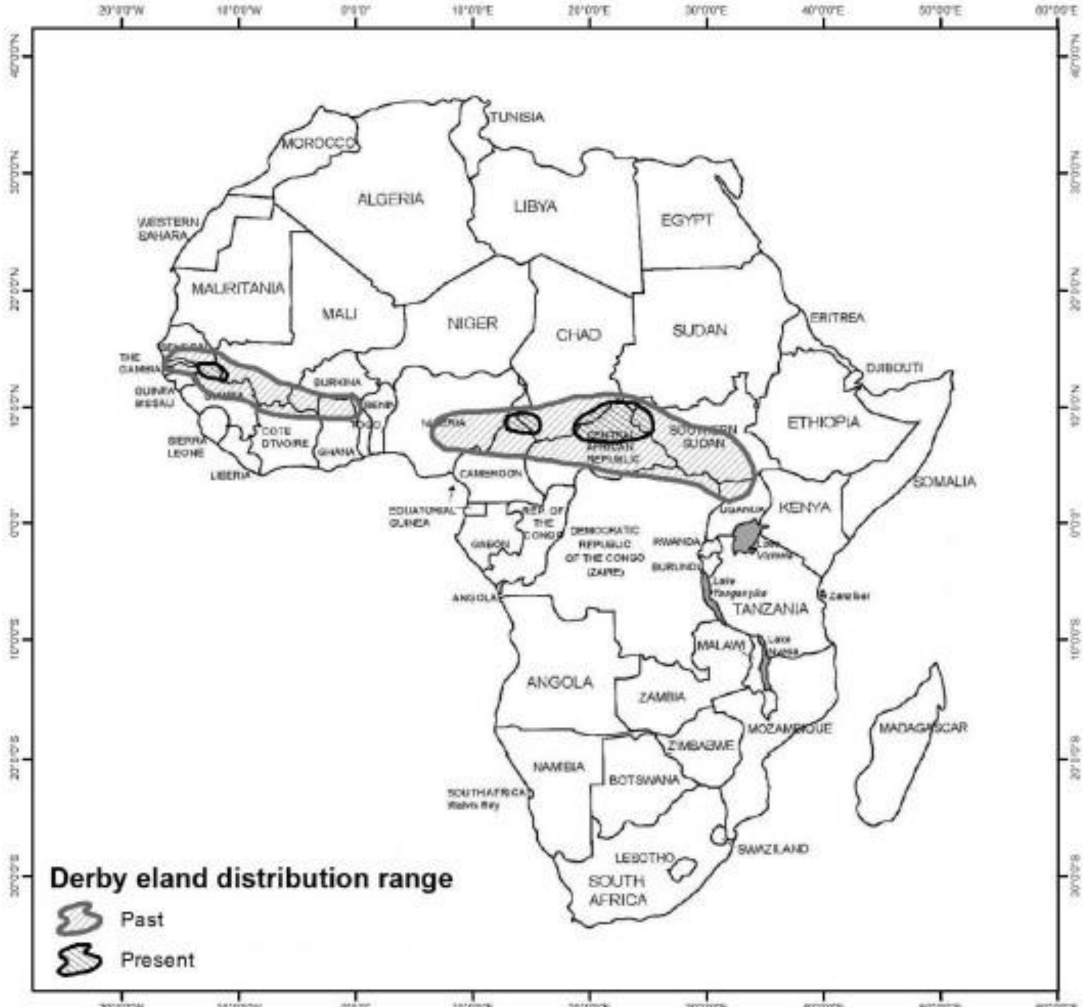


Figure 1: Past and present distribution range of Derby eland (source: Brandlová et al., 2013)

The wild population of Eastern giant eland is mainly distributed in Cameroon and Central African Republic. Total numbers increased since 1990s and are estimated to be 15,000 - 20,000 individuals. Less commonly, they may occur in other countries: Nigeria, Chad, South Sudan, Uganda and Democratic Republic of Congo (IUCN, 2008; McCaffree, 2011).

Derby eland is considered the largest antelope species in the world, it has giant spiraled, V-shaped horns, which can measure more than a meter. Body length is up to 290 cm in males and 220 cm in females. Height at the withers is approximately same as by the common eland and can be over 180 cm. Males are significantly larger than females, which weight about 400 - 500 kg in average, males can reach more than 900 kg. The color of the body varies from beige to brown and help antelopes to hide in the savannah during the dry season. Along the entire length of the back there are 9 – 18 vertical white stripes. As you can see in Figure 2, the torso and neck are above and below bounded by a line of black hair, which can also be found at the top of a long tail. Dark marks are even in the ears, above all the hooves, on the neck, from behind of the front legs, above the knees and along the length of the muzzle. White hair is, besides the stripes, on the inside of the legs and tail, two spots above each hoof, on the mouth, between the eyes and in the ears. From chin to chest stretches typical dewlap (Kolackova et al., 2011; Brandlová et al., 2013; Böhmová, 2013; Kingdon et al., 2013).

Figure 2: Male and female of Western Derby eland (photo: Markéta Švejcarová, 2014)

Morphologically there are small differences between both subspecies, in general, the Western giant eland is a little smaller, darker and has more white stripes than the Eastern giant eland (Kolackova et al., 2011; Lutovská, 2012; Böhmová, 2013). It is necessary to mention, that according to Colin Groves, there are no differences between the two subspecies and he considers them as one species in his Ungulate taxonomy (Groves and Grubb, 2011).

Same as the rest of the antelopes, giant elands are herbivores, almost purely browsers. They feed on more than 30 plant species from African savannah, where they live. Elands eat mostly foliage from the trees and bushes, especially in the dry season. During the rainy season, they add to their diet also grass and fruits. Some examples of the plant species, that foliage creates main part of their diet are *Pterocarpus erinaceus, Ziziphus mauritiana* or *Grewia bicolor*. Favorite fruits are from *Acacia* spp. and *Strychnos spinosa* (Antonínová et al., 2008; Hejcmanova et al., 2010). In both reserves there are different species of plant which eland board with, for example the *Combretum* in Fathala wildlife reserve in Figure 3. Of course, antelopes need to range near to the water sources, even though in the dry season part of their water intake is from the plants.

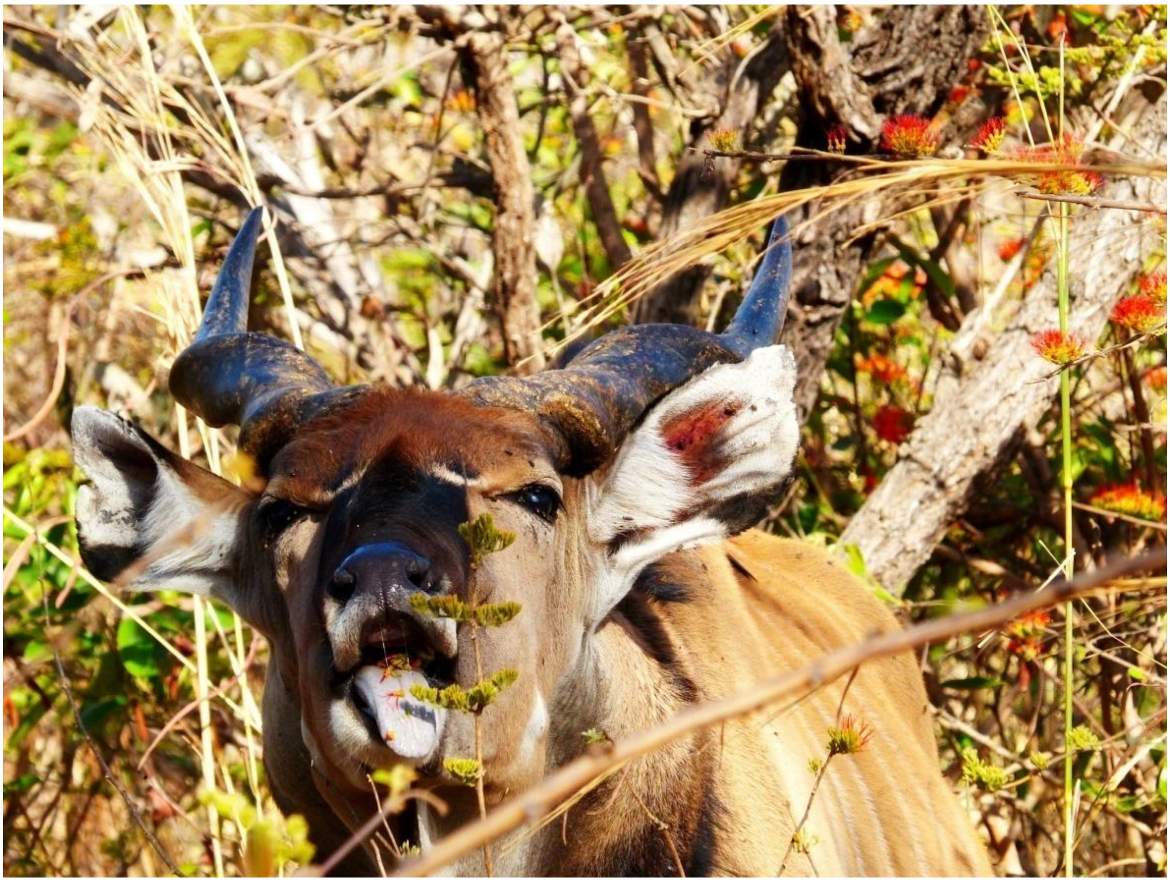


Figure 3: Western Derby eland eating *Combretum paniculatum* (photo: Markéta Švejcarová, 2014)

The herd structure, mating and activities are similar as for the Eastern giant eland. They associate in the herds of several dozen individuals, both sexes, usually led by an alpha male and the rest are females with progeny. Males often fight for the leadership (see Figure 4) and losers live solitary or in bachelor herds. Because of the fights, there may occur more or less serious injuries caused by horns, but in principle, the duel is ritual overprinting. Based on my observation, dominant male can tolerate other adult males trying to copulate with the female in estrus as long as he is focused on other female. They can survive more than twenty years, in Bandia reserve last year died the oldest female in age of 16 years and she was still able to breed (Koláčková et al., 2012; Brandlová et al., 2013).

Females are adult in two years, males reach their maturity between the second and third year of age. In the semi-captivity breeds, females usually have first calf in three years, but also two years old mothers occurred. The earliest conception was in age of 16 months, in average it is around 36 months. Apparently, any transfer of females between herds delays the breeding. Females give birth to usually one calf after nine months of pregnancy (Antonínová et al., 2004; Brandlová et al., 2013; Kingdon et al., 2013).

Figure 4: Western Derby eland males fighting (photo: Markéta Švejcarová, 2014)

2.2 Studbooks

Studbooks are considered to be a base of today's captive breeding. In the past there were unofficial and spoken pedigree data for domestic animals. First released studbook was *General studbook for thoroughbred horses*, published in England by James Weatherby in

1791. It took another more than 100 years for the studbook of a non-domesticated animal to be made. That animal was European Bison (*Bison bonasus*) which was on the brink of the extinction because of poaching. The studbook was an attempt to monitor the rest of individuals and save the species. It was established by European zoo directors based on data by Heinz Heck and published in 1932 (Lackey, 2012).

Each individual in the particular population should be identified by a number (eventually also by a name in small populations, but for computer records are numbers more proper). The pedigree usually starts with the founders, animals who have no known ancestors. That excludes most of the animals in the captivity today to be founders - for those should be possible to trace the original founders from the wild, if the records exist. Mostly, the founders are animals captured from the wild if they reproduce (Ballou et al., 2012). They represent the full genetic diversity in the future population and more founders can be added later if there are more animals remaining in the wild.

The general goal of the studbook keeping is to have a healthy and sustainable population with the highest possible gene diversity. The specific goal can be for example a certain size of the population or reintroduction. Also many problems are related to keeping a studbook. Not all the breeders keep pedigree of their population or they are not willing to provide the data periodically. That causes many blind spaces (Glatston, 1986; Lackey, 2012).

There are several institutions connected with studbook keeping. Most importantly, in 1973 ISIS (International Species Information System) was founded. It is used as central database of wild species in captivity. ISIS works with basic studbook data and provides its members access to the animal database and use of population management software. The database currently contains information about more than two millions animals (Flesness, 2003; ISIS, 2012, 2013). ISIS produce few Animal Record Keeping Software with different assessment that are explained in following chapter Population management.

Studbooks comprise data of a species from certain continent (European, North American... studbooks) or from whole world. International studbooks have to be accepted by IUCN and WAZA to be official. This studbook should contain information of current captive breeding from all over the world and from the past. List of all international studbooks is shown in every publication of International Zoo Yearbook, published by the Zoological Society of London (Flesness and Mace, 1988; WAZA, 2011)

ISIS regularly publishes the ISIS/WAZA Studbook Library DVD. In edition 2011, the DVD included 1540 studbooks, of which were 1350 regional and 190 international studbooks. The total number of assigned studbooks is around 1800 and the DVD represents most of them (WAZA, 2011).

Primary data listed in studbook are divided into demographic and genetic parts. Data in Western Derby eland studbook are chosen for every studbook update differently depending on management plans. Usually there belong:

- Number and name
- Gender
- Date of birth
- Date of death
- Number and name of sire and dam
- Location and the date of emplacement
- Number of stripes on the each flank

These are essential data that are necessary to be observed or chosen. Out of these data, software programs like PMx are able to count population characteristics both demographic and genetic, as well as predict the future development of the population numbers and genetic diversity. Some of the calculations like inbreeding coefficient and mean kinship are listed in the studbook. Studbook of Western Derby Eland also contains photos of each individual from both sides, allowing clear identification.

In 2007, captive population of Eastern giant eland was 53 animals held in 11 institutions (WAZA, 2007). In 2011 studbook update, there are total 54 individuals kept in nine institutions. The biggest population of 25 animals was in White Oak Conservation Center. Before the studbook was established, there were several populations in zoological gardens in Europe and North America, but all animals died until 1980. Current population in North America is from eight founders, captured in Central African Republic and brought to New York State in 1986 (McCaffree, 2011). International studbook keeper is SNDZSP (San Diego Zoo's Safari Park), personally Lissa McCaffree. Today’s situation is critical, according to ZIMS (Zoological Information Management System) report from February 2014, there are only 36 animals left in the captivity breeds. In the one holding institution in Africa, Johannesburg, there are only two old females, so unless more animals would be brought, no breeding is possible. That makes 34 animals (15 males and 19 females) able to breed in the future, in four institutions.

For Western Derby eland, the first studbook was published in 2008, covering the population in semi-captivity from 2000. Since then, four updates were released. The African studbook is managed by Czech University of Life Sciences in a close cooperation with the Society for Protection of Environment and Fauna of Senegal and Directorate of National Parks of Senegal.

2.3 Population management

Population management is indivisible part of nature conservation since its beginning. Basic operations usually consists of manipulation with population size, on one hand support and improving conditions for reproduction, on the other hand establishing carrying capacity and regulation of overpopulation (Williams et al., 2002). With development of scientific methods, population management improved in options and accuracy. Even though most of the big animal species are somehow managed due to their influence on environment, captive and semi-captive breeds are led more punctually. That is enabled by available data, zoos often keep pedigrees of species and it is important there, because small populations are more vulnerable (Lynch et al., 1995; Lacy, 2000).

Goal of population management is the same as of studbook keeping and captive/semi-captive breeding: maintain a sustainable population through demographic and genetic parameters. In genetics, required is gene diversity on at least 90% retained in for a long period, usually 100 years (Foose and Ballou, 1988; Frankham et al., 2010).

Most often used population management software has been developed by ISIS for its members: Medical Animal Records Keeping System (MedARKS), Animal Records Keeping System (ARKS) - provides inventory management. Single Population Analysis & Records Keeping System (SPARKS) - usually used for managing one species and studbook keeping, allows to transfer data to other software such as PM2000 or PMx. Zoological Information Management System (ZIMS) is the latest software produces by ISIS, it provides members to look into pedigrees. ZIMS should incorporate ARKS, MedARKS and SPARKS in the future and serve as a complete database with constant possible access for all members. Other software are Regional Animal Species Collection Plan (REGASP), Single Population Analysis & Records Keeping System (SPARKS) and Physiological Reference Values (AZA, 2013; ISIS, 2013).

Other population management software are PM2000 and improved PMx. They also use pedigree data for demographic and genetic analyses of wild or captive populations with available data. Programs are used by zoo associations all over the world (Lacy et al., 2012).

With habitat loss in developed countries, which affects big mammals particularly, ungulate management is elaborated. Especially in regions with large areas used for agriculture like Europe (Putman et al., 2011) and North America (Weisberg et al., 2002).

There are also software not used for complete population management, but only focused on some influential parameters. As an example there is presented COLONY, created for determining the likelihood of a pedigree; MOL COANC for different set up of founders' relationship than unrelated; KININFOR for estimating the value of molecular information etc. (Fienieg and Galbusera, 2013).

The accuracy and effectiveness of every population management depends on completeness of pedigree data. Molecular genetic data analyses cover different part of genome information, therefore by using only one of the methods, part of the information is missing. The results should not be integrated in average, but evaluated complementary (Fienieg and Galbusera, 2013).

2.4 Small populations

Management of any wild population in conservation programs or captive breeding programs has the same intention: to establish (or keep) healthy population, sustainable for the future. Important part is genetic management, for example control of inbreeding coefficient or maintaining the highest possible gene diversity. In addition, demographic parameters need to be supervised (Ballou et al., 2012; Foose and Ballou, 1988).

The smaller is size of population, the larger risks are attached and the probability of extinction is higher. With low number of founders, the genetic health is compromised from the beginning. Stochastic events are more likely to appear and can have much bigger impact on the stability of population. Besides of genetic risks, even sex ratio imbalance or age distribution can affect the future development. Lynch, Conery and Burger used simulations to find the relationship between the risk of extinction and population size. They found out that every population with effective size smaller than 100 and actual size smaller than 1000 is highly vulnerable to extinction in 100 generations due to genetics related issues (Lande, 1994; Ebenhard, 1995; Lynch et al., 1995; Lacy, 2000).

When the breeding program is established with wild founders, usually there is an assumption that founders are unrelated. Earlier there were no ways to find out the relations between the founders and even today with DNA analyses, it is not common due to high price. In past years, the usage and accessibility of the analyses progress and has been already used in number of captive breeding programs' evaluations (Fienieg and Galbusera, 2013). Lacy and Rudnick calculated that knowing the relationships could help retain the genetic diversity over ten generations up to 2%. In addition, inbreeding level can be to 2% lower (Rudnick and Lacy, 2008).

Also the percentage of known pedigree is an important value. The reliability and accuracy of any calculations made by population management software closely depends on these information. For Eastern giant eland, the pedigree is known 100%; for Western Derby eland there is only 79% of known pedigree in the studbook (Fienieg and Galbusera, 2013; McCaffree, 2013; Brandlová et al., 2013)

As it has been said in previous chapter, the required retention of gene diversity for 100 years is 90%. In small population established with low number of founders, it is often impossible goal. It is necessary to determine achievable goals that suit the specific population. It can be done by settling for the shorter height of diversity or length of the time period. On the other hand, if the population is large enough and well managed the goals can have even increased demands (Frankham et al., 2010; Traylor-Holzer, 2011).

3 Aims of the thesis

In this study, there are three specified aims. The first one is to compare outputs from population management software PM2000 and its newer version PMx. PMx includes all analyses from PM2000 and has some additional, for example stochastic projections (proper for small populations), projections based on scheduled supplementations and/or removals or ability to asses genetic impact of transfers between management groups. Besides these new options, the results from PMx may be a little different, supposedly more accurate and punctual.

The second aim is the comparison of demographic and genetic data for both subspecies *Taurotragus derbianus derbianus* and *Taurotragus derbianus gigas*. From the differences between eastern a western subspecies data, we might gather information about the breeding advance.

As the third aim, there is an evaluation of sustainability of breeding both subspecies in captivity. Based on data from a studbook of Eastern giant eland from San Diego Zoo, it is feasible to estimate the progress of the population in history and calculate the upcoming stage. Same evaluation is made for Western Derby eland; data were taken from Western Derby eland studbooks (2008 - 2012).

4 Methodology

4.1 Materials

Material used in this thesis consists of studbook data of Western Derby eland and Eastern giant eland.

Source of western subspecies' numbers was the latest studbook released as a part of Western Derby Eland (*Taurotragus derbianus derbianus*) Conservation Strategy, Brandlová et al., 2013, published by Czech University of Life Sciences Prague. Data were current until the 21 August 2013. Studbook size was 122 individuals with 92 living animals and there were 41 females and 51 males. At the beginning of the pedigree were the six founders captured in 2000. The whole population is still in Senegal, but separated in two reserves and several herds (some of them non-breeding). Data were collected by participants of the conservation program and employees of the reserves. Because the calves are born during the time interval from November to April, there is an identification running every year in the spring. Identification covers distinction of calves from each other, assessment of its own mother and taking photos. Deaths are not seasonal and the numbers are collected continuously.

Data for Eastern giant eland were provided by San Diego Zoo's Safari Park, which is the studbook keeper for the species. Data from SPARKS were current through 10 October 2013. The full studbook size was 267 animal, with 49 living animals kept in 9 institutions. In population there were total 25 females and 24 males. Population was established with 8 founders from the wild. The studbook is international and keeping institutions are mostly from North America, but also from South Africa and since 2012 United Arab Emirates. The studbook covers the historical population through the world, but the living population shares no genes with them and including them in the analysis would provide irrelevant results. Therefore the population was selected and in the analysis were used only data for animals that come out of the 8 founders. From living population that resolution excluded only 2 females kept in South Africa.

4.2 Data analyses

Software programs used for processing the studbook data are PM2000 and PMx. Both of them are free for downloading through website www.vortex9.org and www.vortex10.org. JP Pollak (Cornell University), Jonathan Ballou (National Zoological Park) and Robert Lacy (Chicago Zoological Society) developed these programs for population management. Latest version of PM2000 is from 2007, then was released PMx in 2010 as next level of the software.

In the analyses, there were compared several demographic and genetic parameters. Out of demography, those were graphs of age distribution and seasonality and values of population size, sex ratio, generation length, and life-table lambda. In genetics, there were compared gene diversity and potential gene diversity; mean inbreeding; founder genomes equivalents (FGE) and potential FGE.

In seasonality, PMx uses above the graph visualization, also Chi-square and P value. Chi-square is a statistical test used to express probability of observed event to occur by chance. P stays for uniform distribution, when the number is < 0.05, the data are significantly seasonal (Traylor-Holzer, 2011).

In demography there is compared sex ratio. The best distribution can be different between the species. Ideally, it should guarantee the highest possible number of descendants, considering the social structure of species. It means that for the species, which live in monogamist relationships (such as white stork), it is desired for the ratio to be balanced 1:1. Polygamist and promiscuity species are much more effective when there are more females than males. The ratio again depends on the species; the animals can reproduce in triads or herds. It can deteriorate due to poaching, but also it can be reformed by well managed harvesting (Frankham et al., 2010).

Generation length can be defined as the time interval from the midpoint in reproduction period of one generation to the midpoint in the reproduction of the next generation (Merrell, 1994). Generation length proportionately influences the effective population size. As you can see in Figure 5, the longer it is, the smaller is the population size needed to maintain 90% of genetic diversity in 100 years. There has been already established a database of generation lengths for mammalian species (Frankham et al., 2010; Pacifici et al., 2013).

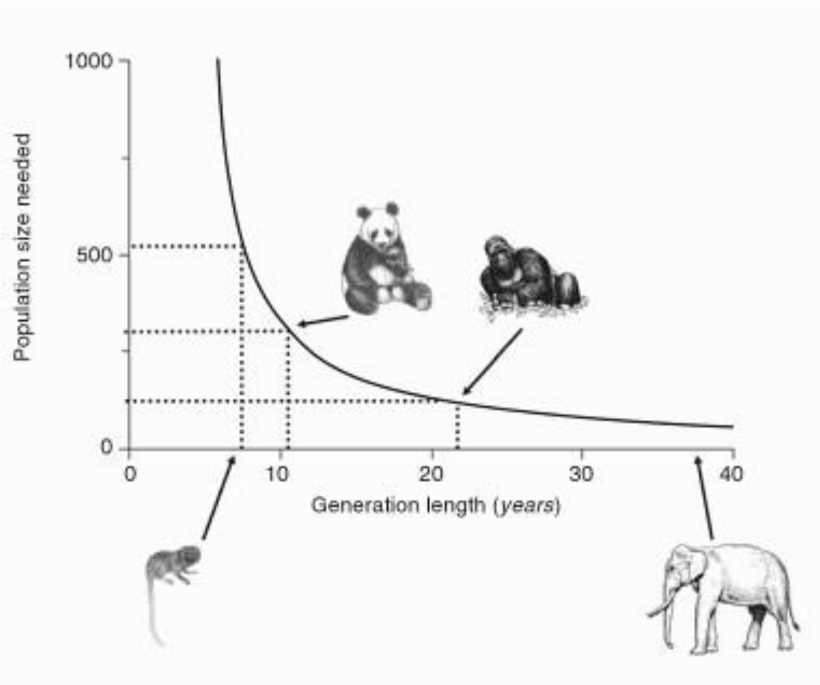


Figure 5: How generation length affects the effective population size (source: Frankham et al., 2010)

Gene diversity is an important value for setting the goal of the specific conservation breeding. Certain level of gene diversity is the most often goal for the future of many captive breeding.

Then there is inbreeding coefficient, desired to be as low as possible. Mean inbreeding express an average inbreeding coefficient of an individual in the population.

Founder genome equivalents reflect the number of founders that would maintain the same gene diversity as in current population. The number is decreasing with loss of alleles in population (Traylor-Holzer, 2011).

5 Results

5.1 Comparison of studbook analyses results in software PM2000 and PMx

Studbook data for Western Derby eland were chosen to compare results in both versions.

Age Distribution

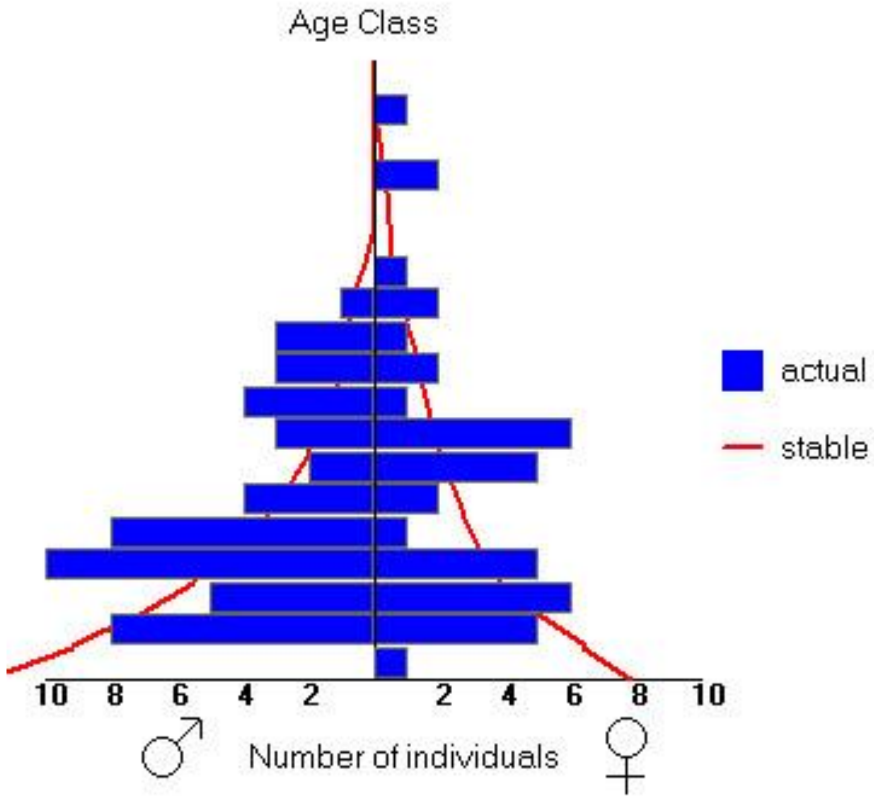
The age structure graphs showed number of males (on the left side) and females (on the right side) in different age classes. Blue color indicated reproductive individuals.

Software PMx offered additional visual display of non-reproductive animals, indicated by light blue color, in this case, all of them were present sub adults and juveniles. Furthermore, PMx graph showed total number of males and females and the scale of age is included in the graph.

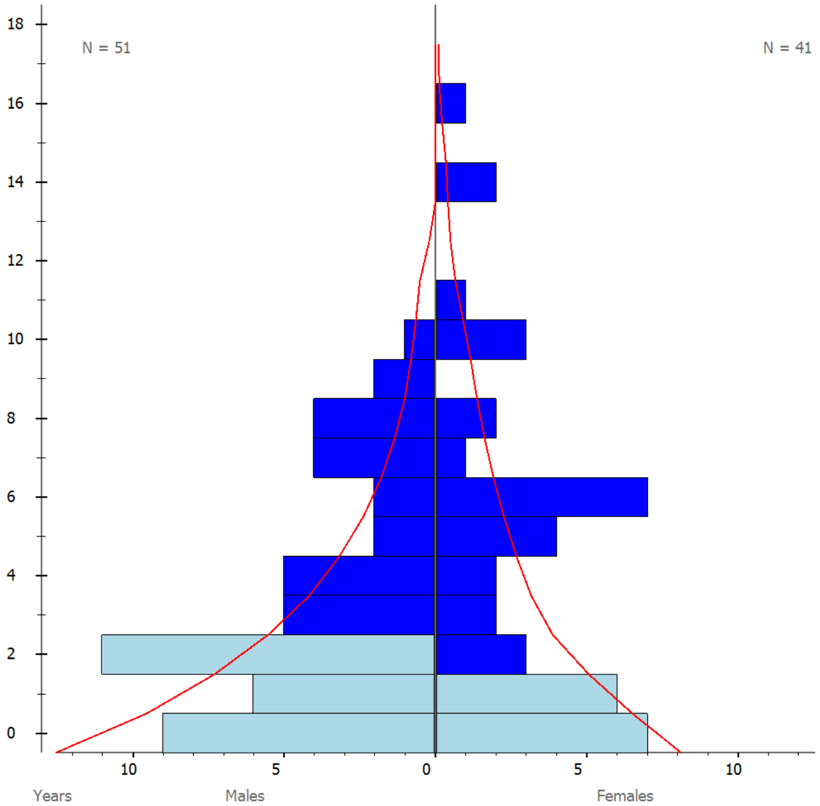
Apart from this, graphs showed the same results.

The population size was 92 individuals in total, including 51 males and 41 females. The sex ratio of males to females was then 1.2:1. Generation length was 6.47 (6.8 for males and 6.1 for females) in PMx and 6.41 in PM2000. The age structure with wide base indicates population growth.

PMx software also displayed an age structure impact by sentence, that the actual growth rate of population was moderately less than predicted. The growth based on life-table lambda was 1.22.



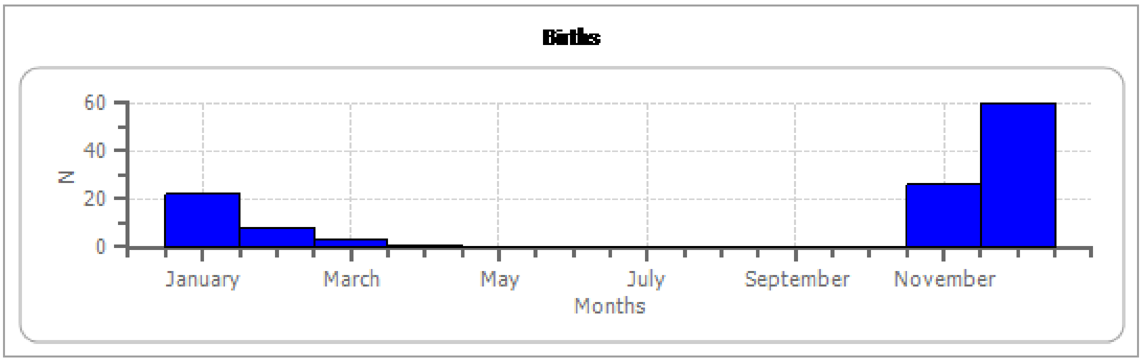
Graph 1: Age distribution of Western Derby eland (source: PM2000)



Graph 2: Age distribution of Western Derby eland (source: PMx software)

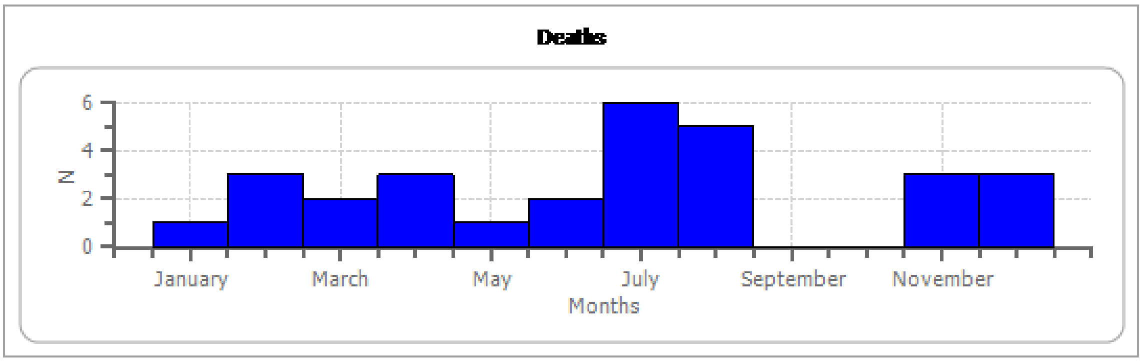
Seasonality

Seasonality data were one of the new features in PMx, PM2000 did not provide this option.



Graph 3: Births distribution of Western Derby eland (source: PMx software)

The births graph showed the seasonality in natural conditions (chi-square = 363.40; $p < 0.05$). There were 122 births in total. Except occasional cases, most of births occurred from October to March. With knowing the pregnancy period, we could count the rut interval was from December to July. That assumption was confirmed by observation. The earliest reproduction was in two years for female and three years for male.

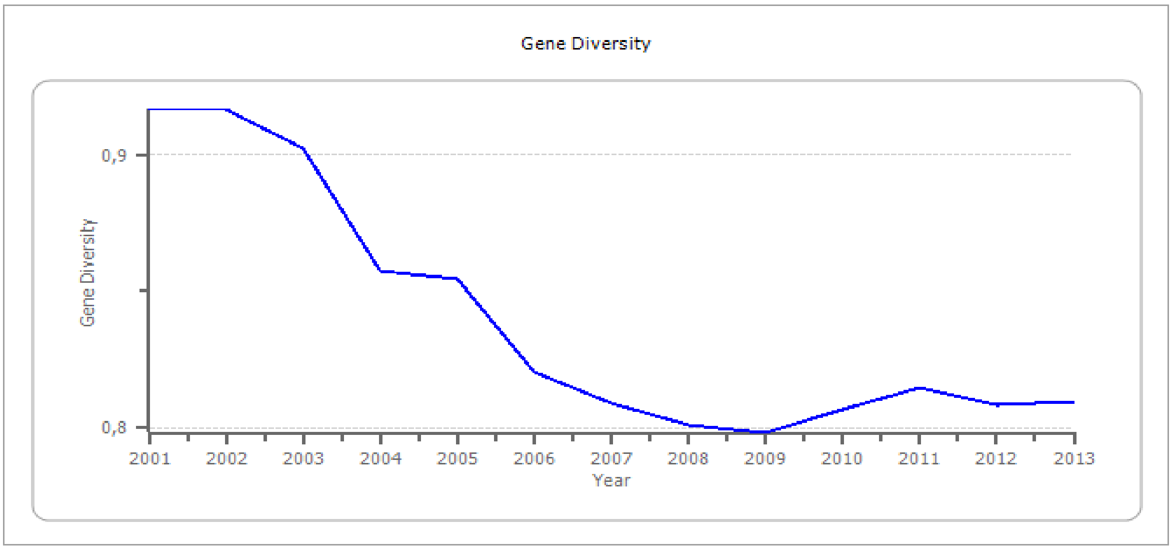


Graph 4: Deaths distribution of Western Derby eland (source: PMx software)

Most deaths occurred in July and August, which answers to the rainy season in area of extension, Senegal. Despite of this, the death distribution was not significantly seasonal (chi-square = 15.28; $p > 0.05$).

Gene Diversity

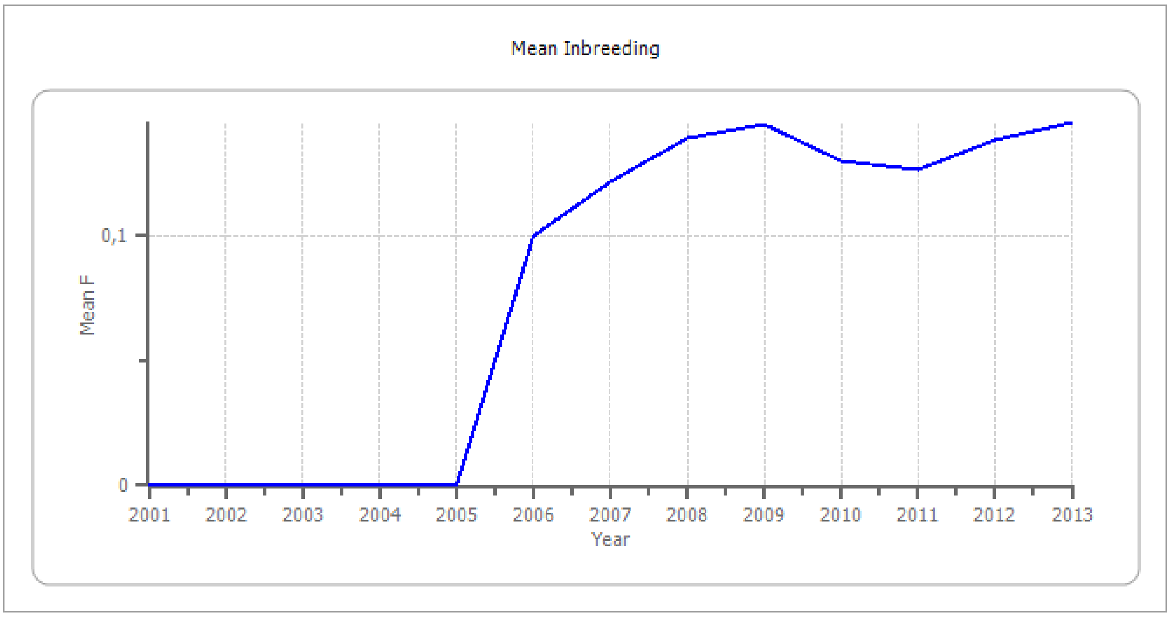
PM2000 did not create graph for the development of gene diversity due to insufficient data, but calculated its value for current data. In PM2000, the gene diversity was 0.7930 and potential was 0.9161. The diversity based on kinship matrix was 0.7930 and diversity based on gene drop was 0.7928. The potential was 0.9162.



Graph 5: Gene diversity of Western Derby eland (source: PMx software)

Mean inbreeding

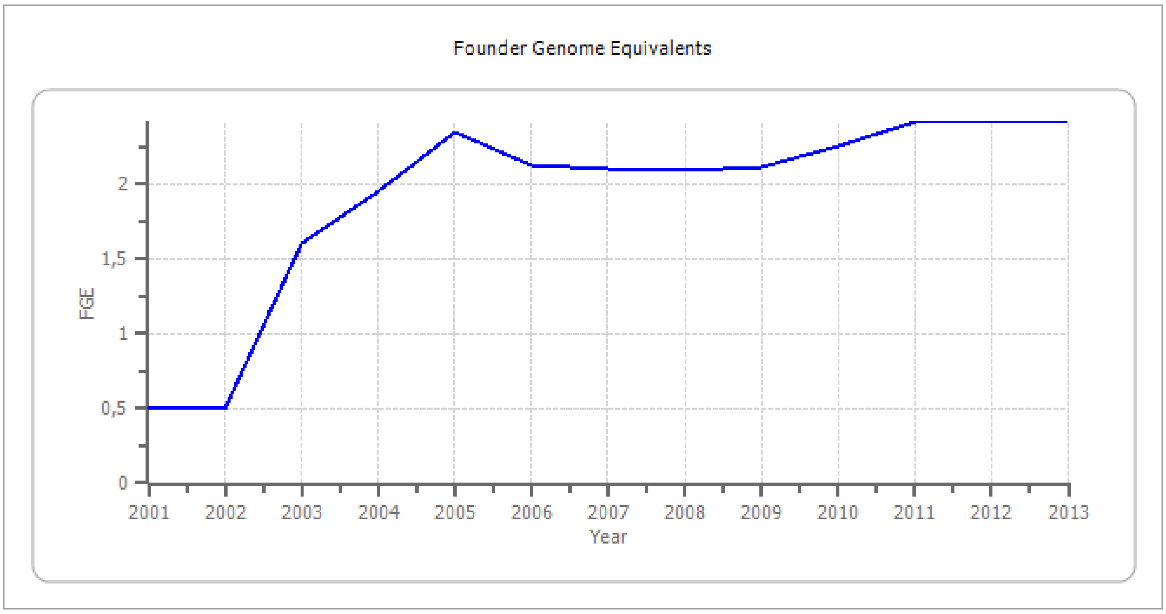
PM2000 did not create a graph of the development for mean inbreeding due to insufficient data and calculated the current value on 0.1223. PMx counted the mean inbreeding 0.1483.



Graph 6: Mean inbreeding of Western Derby eland (source: PMx software)

Founder Genome Equivalents

PM2000 did not provide a graph of the development for FGE due to insufficient data. The current value was 2.42 and potential 5.96. As for gene diversity, PMx offered two different numbers for FGE. Both numbers (based on gene drop and based on kinship matrix) were 2.42 and the potential was the same.



Graph 7: FGE for Western Derby eland (source: PMx software)

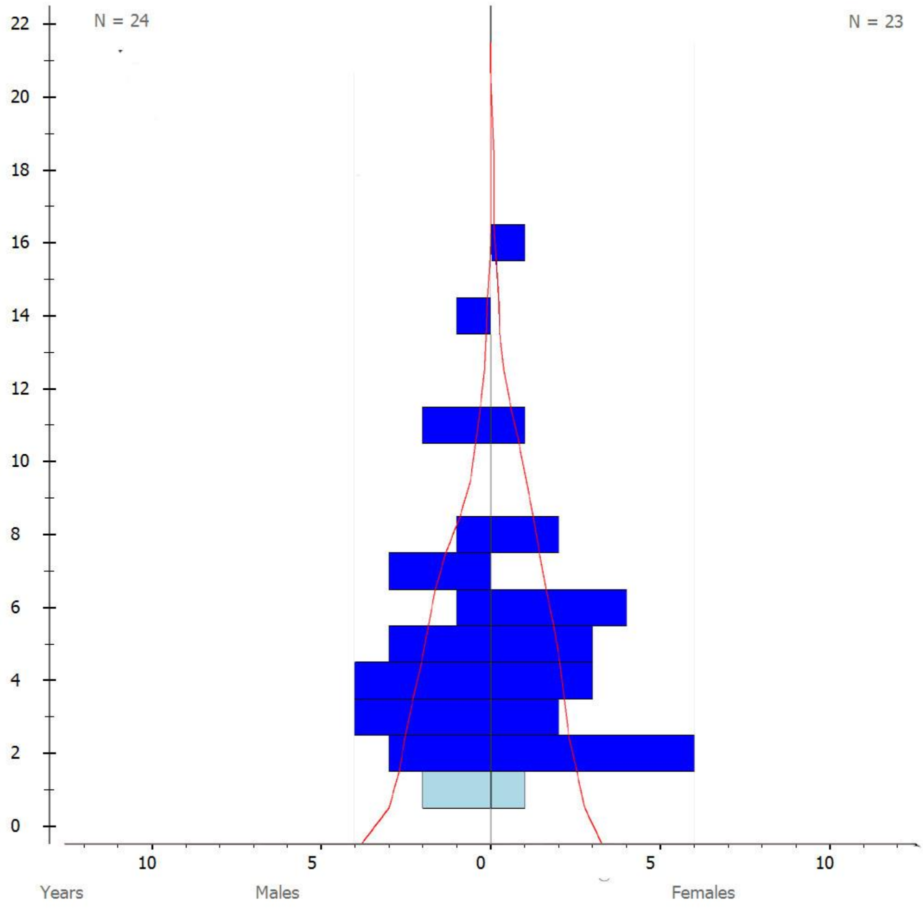
5.2 Comparison of demographic and genetic parameters *Taurotragus derbianus derbianus* and *Taurotragus derbianus gigas* in PMx

Age Distribution

Males were showed on the left side and females on the right side, in different age classes. Blue color indicated reproductive individuals, light blue non-reproductive individuals, which were in the population sub adults.

The age structure showed naturally only living animals and the age of the oldest living animals was comparable in both populations.

The highest reached age was 20 years (Eastern giant eland female) and the latest reproduction was in age of 19 years.



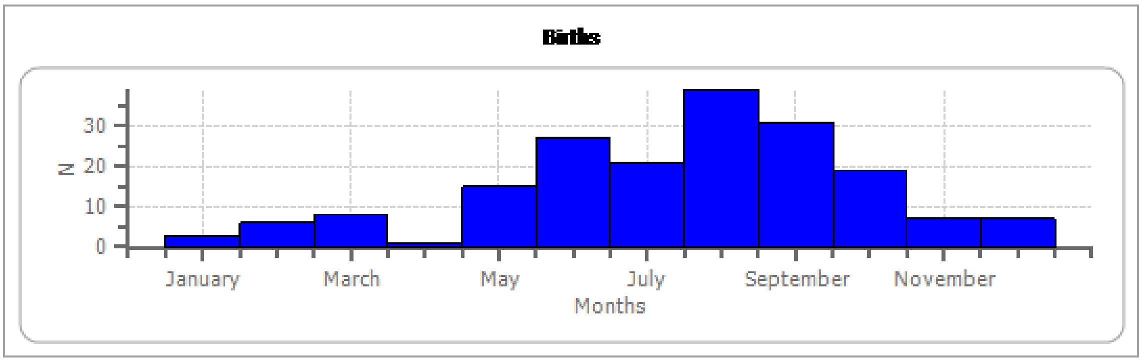
Graph 8: Age distribution of Eastern giant eland (source: PMx software)

The population size was 47 individuals, including 24 males and 23 females. The sex ratio was 1.04:1 of males to females; slightly lower than for Western Derby eland.

Generation length was 6.81 (7.1 for males and 6.5 for females).

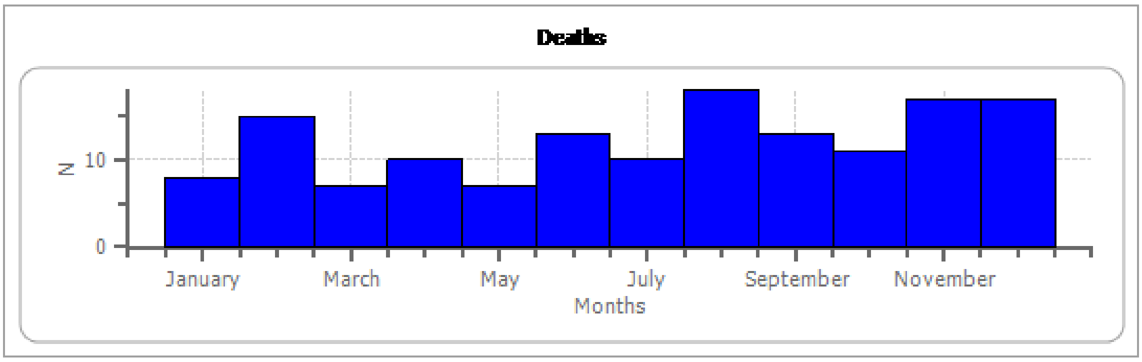
It was obvious, that number of descendants was decreasing. Status of growth in PMx was following: Significant chance, that the population would decrease instead of increase as predicted. Life-Table Lambda for growth was 1.04.

Seasonality



Graph 9: Births distribution of Eastern giant eland (source: PMx software)

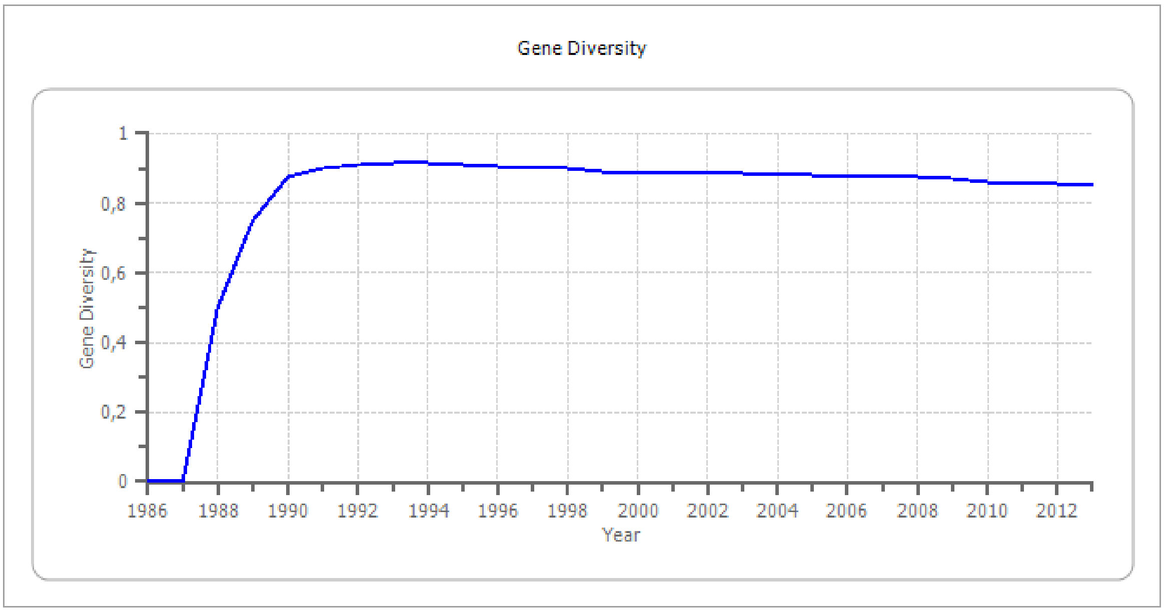
Births showed the seasonality pattern (chi-square = 105.96; $p < 0.05$). The most births appeared in August and in summer time in general, but some births were distributed throughout the whole year. The earliest reproduction was in two years for both males and females.



Graph 10: Deaths distribution of Eastern giant eland (source: PMx software)

In captivity, the deaths were not seasonally distributed, values were more or less equable during the year (chi-square = 14.11; $p > 0.05$).

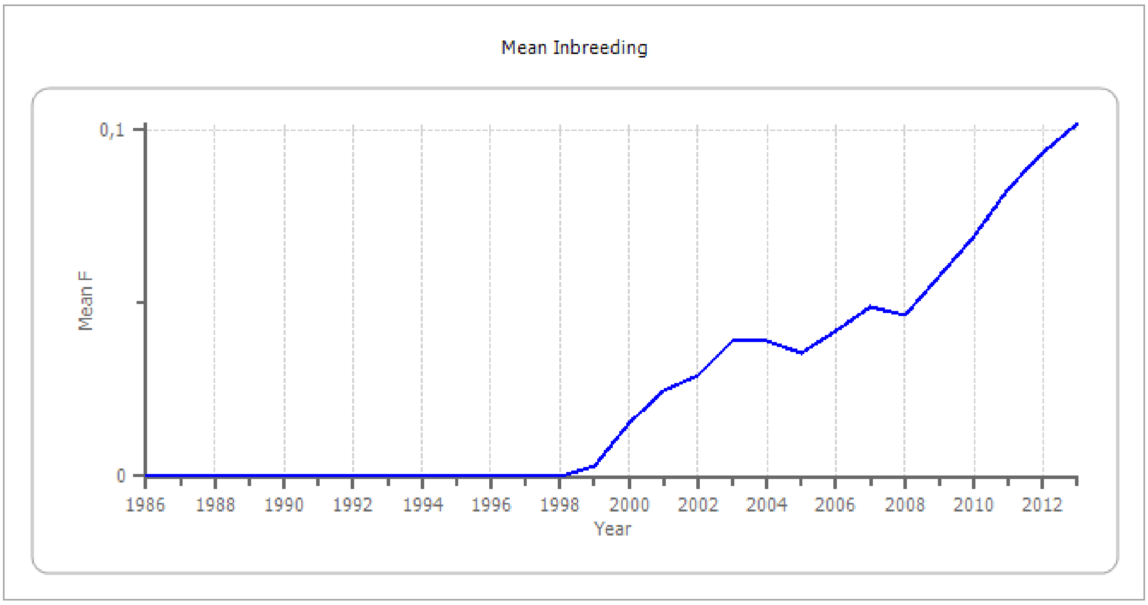
Gene Diversity



Graph 11: Gene diversity of Eastern giant eland (source: PMx software)

Gene diversity was 85.20 and potential was 0.9125. Diversity was slowly decreasing, but potential was significant.

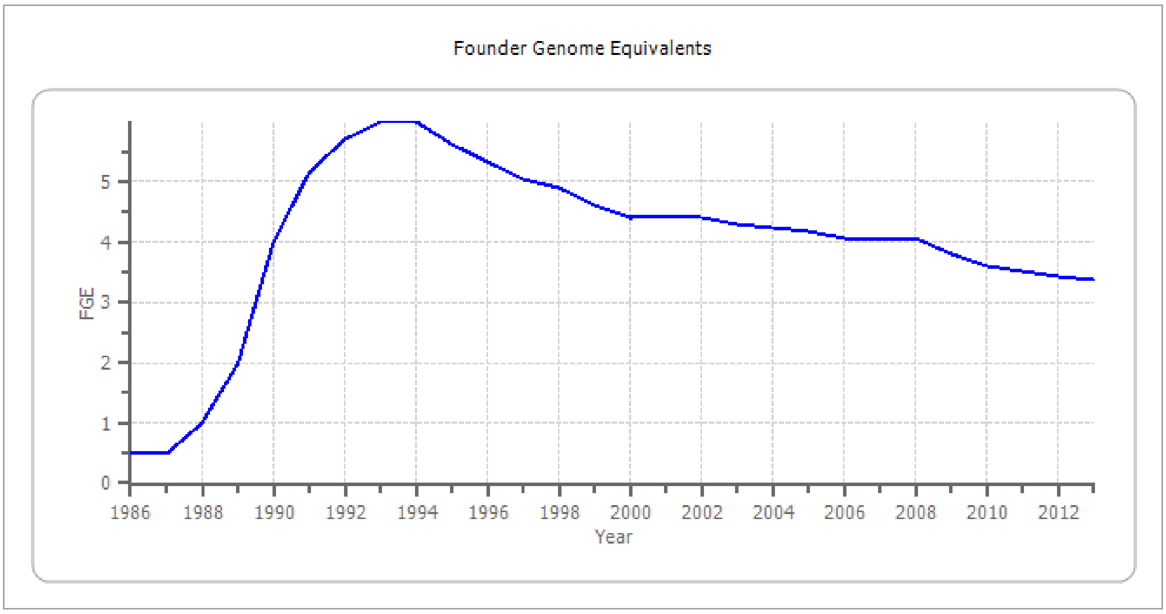
Mean Inbreeding



Graph 12: Mean inbreeding of Eastern giant eland (source: PMx software)

The mean inbreeding was 0.1017 and increasing.

Founder Genome Equivalents

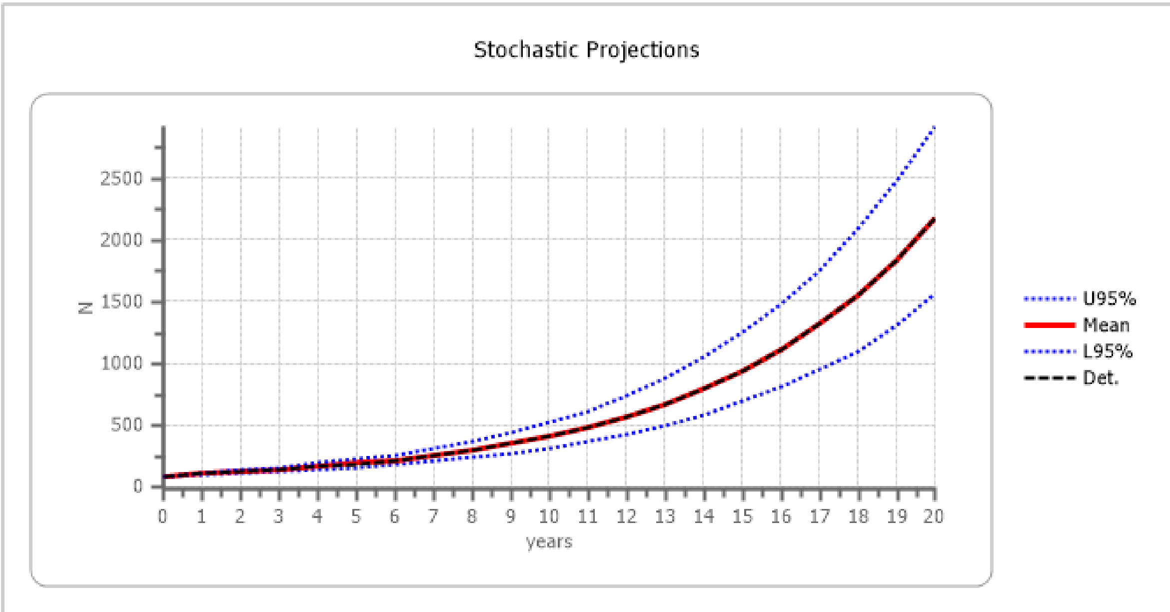


Graph 13: FGE for Eastern giant eland (source: PMx software)

FGE in population of Eastern giant eland were 3.38 and potential 5.71.

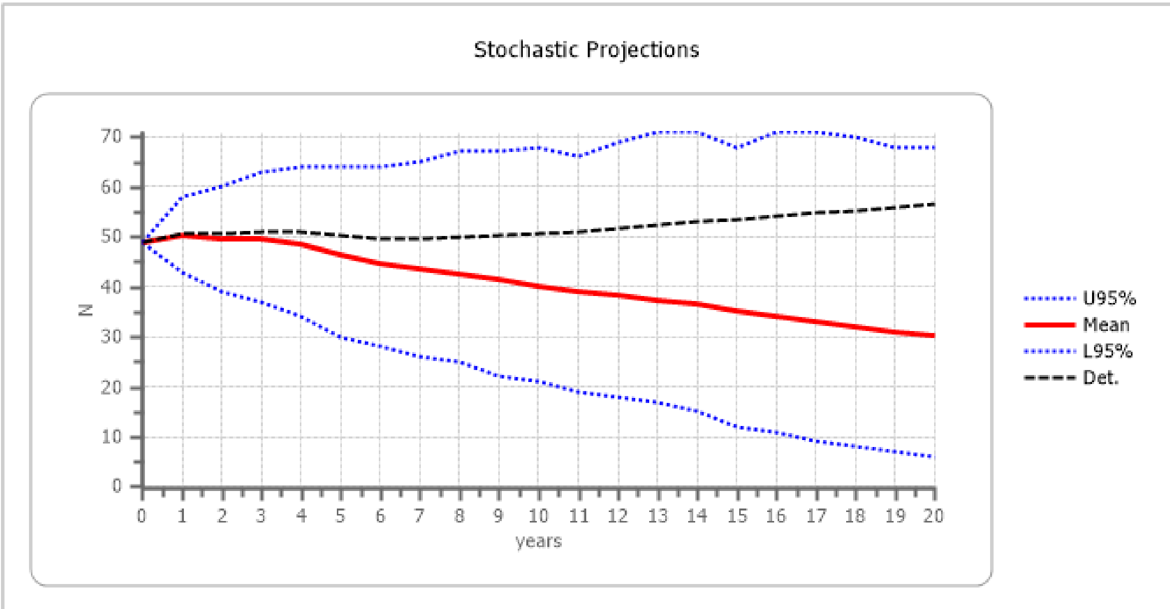
5.3 Estimation of sustainability of both populations in human care

For the future development of population, PMx offered sections “Projections”. There was stochastic projection for graph of general size of population in time period of twenty years.



Graph 14: Stochastic projection for Western Derby eland (source: PMx software)

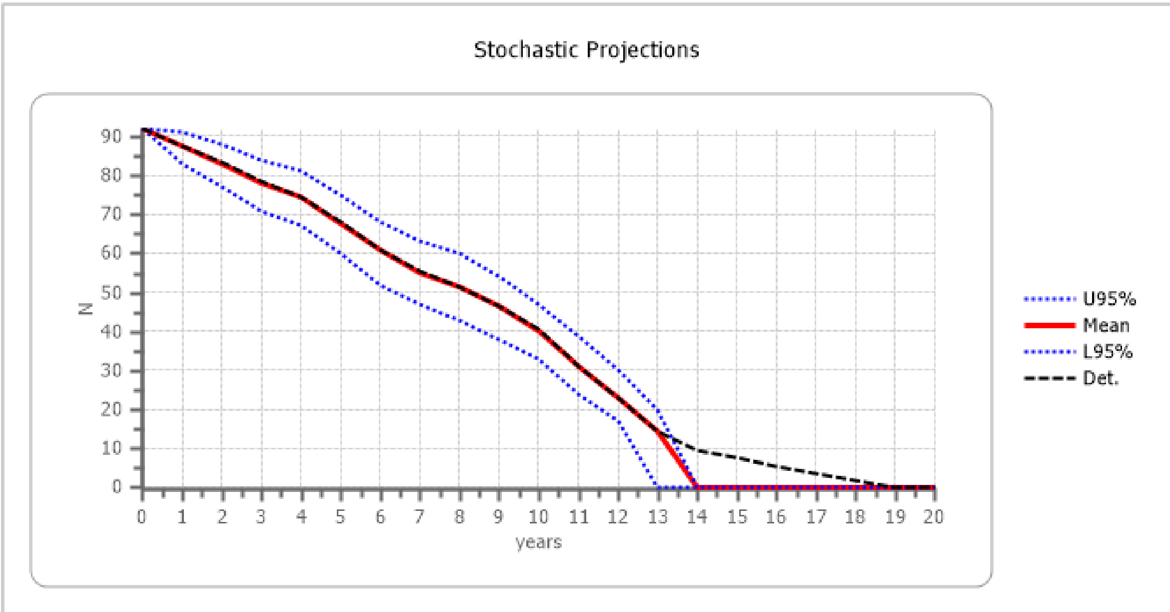
For Western Derby eland, the prognosis was: probability of extinction 0.00. The probabilities of size next year were: 0.00 for decline, 1.00 for increase and 0.00 for the same size.



Graph 15: Stochastic projection for Eastern giant eland (source: PMx software)

For Eastern giant eland was the prognosis following: probability of extinction 0.00. The probabilities of size next year were approximately: 0.12 for decline, 0.78 for increase and 0.10 for the same size.

There is a possibility to make a projection for the situation that no animals would breed. That is useful for visualization of the time period that detaches the population from extinction in the worst case.



Graph 16: Stochastic projection for Western Derby eland without births (source: PMx software)

Another tool for modelling the future was section “Goals”. There user could count necessity of new founders supplementation to the population in order to reach defined goal. The goal was always to retain certain level of gene diversity during or at the end of chosen time period.

For illustration there was set goal to maintain 90% of gene diversity at the end of 100 years as the basic recommended goal for conservation breeding, while maximum allowable population size was 500 individuals. For Eastern giant eland it was required to add 9 founders in total, gene diversity would have been 90.6% and would remain over 90% up to 106 years. For Western Derby eland would have been sufficient to add 7 founders in total, gene diversity would have reached 90.7% and would have stayed over 90% up to 108 years.

6 Discussion

6.1 Comparison of studbook analyses results in software PM2000 and PMx

PMx provides several new features, not presented in PM2000 before (Traylor-Holzer, 2011). There were some more or less significant deflections in the results.

The whole age structure is distributed differently in both software and the generation length varies by 0.06. This is due to approach to age. PM2000 splits up the animals based on in which year they were born and PMx counts with their actual age. This would not matter for species that have births distributed during the year, but because Western Derby elands give births at the turn of the year (peak December to January), PMx shows the real situation.

The ability of PMx (unlike PM2000) to create the genetic graphs out of the same amount of data shows the progress in software's efficiency. The two types of expression gene diversity and founder genome equivalents accordingly to if the calculations are based on gene drop or kinship matrix make the results more reliable on. Pursuant to the results, PM2000 used the calculation based on kinship matrix (the numbers are identical) (MacCluer et al., 1986).

There is 0.01 severance in potential gene diversity. This is probably because it is calculated from FGE, where is the same severance (Traylor-Holzer, 2011).

The most significant difference is in mean inbreeding, 0.026. Supposedly this could be caused by distinctive formulas for calculation. For PM2000 there were not found specific used formulas, therefore this conclusion is not certain. It can be assumed, that if there was used another formula in PMx, it was to get improved results and this number would be factual.

For founder genome equivalents the same results came out except for potential. There is no reason for this 0.01 difference. The cause may be the same as before, different way of calculation.

Out of the new features, for example following are very useful. An option to remove some animals from model population is needful especially for the breeding with possibility of transferring animals. Out of the calculations there can be made the decisions for example which animal is the least needed in the population and can be transferred or which one is overrepresented in gene diversity and should be removed. Besides transfers, same principle can be applied with harvesting animals for trophies so there is no (or the smallest possible) negative impact for the conservation breeding (Milner et al., 2007).

Supplementation of animals into population can be used to choose the location (herd) where the specific animal should be brought. If the animal has known pedigree data, it can have a different influence in each group.

Especially for conservation program for Western Derby eland, the possibility to count with multiple possible parents is very useful. For animals living in groups, it is not always easy to be sure of one sire and one dam for each offspring (Perez-Enciso and Fernando, 1992; Lacy et al., 2012).

6.2 Comparison of demographic and genetic parameters *Taurotragus derbianus derbianus* and *Taurotragus derbianus gigas* in PMx

Demography

Total size of population is almost twice higher in population of Western Derby eland in spite of the fact, that Eastern giant eland’s population comes from two more founders and the breeding is led for more than twice longer. The fact that Eastern giant eland’s population is much more fragmented and not all the holding institutions participate on the management actively highly influences those values. There were also groups of alone females without the possibility to breed (Dooley Jr and Bowers, 1998; Williams et al., 2002; McCaffree, 2011; Brandlová et al., 2013).

Even though the oldest living animals are currently same age, there is significant difference in highest age reached at all. In population of Eastern giant eland, the animal was able to survive for four more years than the oldest Western Derby eland and reached age of 20 years. There are no predators that could endanger adult eland in the reserves in Senegal, but the conditions can be considered more severe in general. In the zoo, unlike from the reserves, there is always present veterinary care (McCaffree, 2011; Müller et al., 2011; Brandlová et al., 2013).

Age structure of Eastern giant eland does not have the wide basis contrary to Western Derby eland, because the population is decreasing instead of increasing. This also arising from the values of lambda (McCaffree, 2011; Brandlová et al., 2013)

As for polygamist species, the ideal sex ratio of females to males would be 1<1:1. It means that better ratio has the Eastern giant eland (Frankham et al., 2010).

As long as the range is large enough and the carrying capacity is not an issue, the generation length is better shorter. That definitely holds for both populations and shorter length has Western Derby eland. That is one reason why the population growth rate is higher, so that the population is increasing (Frankham et al., 2010; Pacifici et al., 2013).

It is not feasible objectively compare seasonality of births, because in captivity it depends on breeding strategy: if the males and females are held together or permitted under control. In the reserves, Western Derby elands have the births distributed through the dry season. It is the matter of survival strategy, there is less vegetation, but the calves are dependent on mothers' milk and the rainy season is more exacting for the animals.

For all parameters, it is necessary to consider singularities in the breeding of both populations. Semi-captivity of Western Derby eland population in both reserves Bandia and Fathala is quite similar to wildlife conditions. Contrary to Eastern giant eland, which is kept in zoos and similar institutions. Also captivity enables other ways of management. Different climate can be affective. And not least the diet and available area.

Genetics

The most important impact on the distinctness in the results of genetics has probably the different number of founders. Even only two more founders affect significantly all parameters.

As a result, in gene diversity all the numbers came out better for Eastern giant eland population. Also the lower value to reach the potential diversity is convenient. Western Derby eland population's diversity is increasing and the other one is again decreasing.

Mean inbreeding is higher for Western Derby eland. There are no specific categories for impact of certain level of inbreeding, which makes any evaluation more difficult. In any case, considering collapse of populations Eastern giant eland in history (population in South Africa), inbreeding is one of the most beware values (McCaffree, 2011).

Although value of founder genome equivalents is also higher for Eastern giant eland, it is rapidly decreasing since 1991, when all eight founders were included in breeding. In contrary, in population of Western Derby eland is it sustained approximately same and increasing thanks to management (McCaffree, 2011; Brandlová et al., 2013).

It is essential to use more ways of attitude to population management. Although using software provides many useful information, analyses based on molecular genetic data offer another results that should be weight up and can be significantly distinctive from the results of software analyses (Fienieg and Galbusera, 2013).

6.3 Estimation of sustainability of both populations in human care

Stochastic projections vary in both populations but neither one of them is close to the extinction in the nearest future. It is obvious, that population of Western Derby eland has much better prognosis for the next twenty years. However, there is no reason, why population of Eastern giant eland should decrease, since no parameters are insurmountably bad and the potentials are still promising.

Out of the results from “Goals” section, it is apparent, that population of Western Derby eland has lower demands to maintain the high gene diversity. In theory, it would mean, that it is easier to accomplish that.

The sustainability in general for the future can be modified mainly by supplementation of new founders to both populations. As all genetic parameters show, the number of founders is more affecting than population management is able to. Therefore, the actual sustainability relies most importantly on existence of any option to bring new founders from the wild. In general that goal is more realizable for Eastern giant eland. In wild there is still remaining significantly large gene pool. Wild population of Western Derby eland is numerically doubtable and extremely lower. In spite of all this, still other (financial, political etc.) factors can change the feasibility (Koláčková et al., 2011).

7 Conclusion

Population management software PM2000 and PMx offered different results in several situations. The new version used some improved calculations, therefore results for those parameters varied. Those outputs of PMx were more reliable, accurate and relevant for the current status of breeding. Other formulas remained the same and the results were identical. New features facilitate management of conservation breeding and provide an option of more complex and wider control over the population. PMx is a great progress in population management software.

Population of Eastern giant eland showed better qualities in most of the studied parameters contrary to Western Derby eland. In demographic section, as the most influential was assumed the distinctive conditions of breeding and population management. In genetics was crucial the number of founder. Slightly higher number of founders affected all the results significantly.

The future projections looked more promising for Western Derby eland. That was thanks to population management, the status of the major part of the parameters was progressive. Problem of Eastern giant eland' population is partly in fragmentation of the breeding, but with the current potentials, it is still sustainable. That holds for both populations, especially with possibility to bring new founders.

8 References

Antonínová M, Hejcmanová P, Koláčková K, Verner P. 2008. African Studbook. Western Derby eland, *Taurotragus derbianus derbianus* (Gray, 1847). Prague: Czech University of Life Sciences Prague.

Antonínová M, Hejcmanová P, Váhala J, Mojžíšová L, Akakpo AJB, Verner PH. 2006. Immobilization and transport of Western giant eland (*Taurotragus derbianus derbianus*) from the Bandia reserve to the Fathala reserve in Senegal. Gazella. Prague: Zoo Praha, p75-98.

Antonínová M, Nežerková P, Vincke X, Al-Ogoumrabe N. 2004. Herd structure of the giant eland (*Taurotragus derbianus derbianus*) in the Bandia Reserve, Senegal. Agricultura Tropica et Subtropica, p1-5.

AZA. 2013. Animal Records Keeping Software. Available at http://www.aza.org/animal-data-and-records-software/: Accessed 2014-03-26.

Ballou J, Lees C, Faust L, Long S, Lynch C, Lackey L, Foose T. 2012. Demographic and Genetic Management of Captive Populations. Kleiman D, Thompson K, Baer C editors. Wild Mammals in Captivity: Principles and Techniques for Zoo Management. Chicago: University of Chicago Press, p720.

Brandlová K, Mallon D, Hejcmanová P, Regnaut S, Jůnková Vymyslická P, Fedorova T, Žáčková M, Brandl P, Ndiaye S. 2013. Western Derby eland (*Taurotragus derbianus derbianus*) Conservation Strategy. Prague: Czech University of Life Sciences Prague. 111p.

Bro-Jorgensen J. 1997. The Ecology and Behaviour of the Giant Eland (*Tragelaphus derbianus*, Gray 1847) in the Wild. Copenhagen: University of Copenhagen, p106.

Böhmová Z. 2013. Coat pattern of Western Derby Eland (Taurotragus derbianus derbianus) - an evidence for heritability? [MSc]. Prague: Czech University of Life Sciences Prague.

Dooley Jr JL, Bowers MA. 1998. Demographic responses to habitat fragmentation: experimental tests at the landscape and patch scale. Ecology 79: 969-980.

Dorst J, Dandelot P. 1972. Larger Mammals of Africa: Collins.

East R. 1999. African Antelope Database 1998: IUCN Species Survival Commission.

Ebenhard T. 1995. Conservation breeding as a tool for saving animal species from extinction. Trends in ecology & evolution 10: 438-443.

Fienieg ES, Galbusera P. 2013. The use and integration of molecular DNA information in conservation breeding programmes: a review. Journal of Zoo and Aquarium Research 1: 44-51.

Flesness N. 2003. International Species Information System (ISIS): Over 25 years of compiling global animal data to facilitate collection and population management. International Zoo Yearbook 38: 53-61.

Flesness N, Mace G. 1988. PopuIation databases and zoological conservation. International Zoo Yearbook 27: 42-49.

Foose T, Ballou J. 1988. Management of small populations. International Zoo Yearbook 27: 26-41.

Frankham R, Ballou JD, Briscoe DA. 2010. Introduction to Conservation Genetics: Cambridge University Press.

Glatston A. 1986. Studbooks: the basis of breeding programmes. International Zoo Yearbook 24: 162-167.

Groves C, Grubb P. 2011. Ungulate Taxonomy: Johns Hopkins University Press.

Hejcmanova P, Homolka M, Antoninova M, Hejcman M, Podhajecka V. 2010. Diet composition of western Derby eland (Taurotragus derbianus derbianus) in the dry season in a natural and a managed habitat in Senegal using faecal analyses. South African Journal of Wildlife Research 40: 27-34.

Hájek I, Verner PH. 2000. Aerial census of big game in Niokolo-National Park and Falemé Region in Eastern Senegal. 3rd All Africa Conference on Animal Production. Alexandria.

ISIS. 2012. International Species Information System. Available at http://www2.isis.org/AboutISIS/Pages/About-ISIS.aspx: Accessed 2014-02-20.

ISIS. 2013. ARKS Workbook. Available at http://www2.isis.org/support/ARKS/Pages/home.aspx: Accessed 2014-03-26.

IUCN. 2008. The IUCN Red List of Threatened Species. Available at http://www.iucnredlist.org/details/22059/0: Accessed 2014-01-10.

Kingdon J, Happold D, Butynski T, Hoffmann M, Happold M, Kalina J. 2013. Mammals of Africa: Bloomsbury Publishing.

Kolackova K, Hejcmanova P, Antoninova M, Brandl P. 2011. Population management as a tool in the recovery of the critically endangered Western Derby eland Taurotragus derbianus in Senegal, Africa. Wildlife Biology 17: 299-310.

Koláčková K, Vymyslická P, Hejcmanová P, Haberová T, Žáčková M, Brandl P. 2012. African Studbook. Western Derby Eland, *Taurotragus derbianus derbianus* (Gray, 1847). Prague: Czech University of Life Sciences Prague.

Lackey L. 2012. Appendix 3. Records, Studbooks, Regional Zoo Associations, and ISIS. Kleiman D, Thompson K, Baer C editors. Wild Mammals in Captivity: Principles and Techniques for Zoo Management. Chicago: University of Chicago Press, p720.

Lacy R, Ballou J, Pollak J. 2012. PMx: software package for demographic and genetic analysis and management of pedigreed populations. Methods in Ecology and Evolution 3: 433-437.

Lacy RC. 2000. Considering threats to the viability of small populations using individual-based models. Ecological Bulletins: 39-51.

Lande R. 1994. Risk of population extinction from fixation of new deleterious mutations. Evolution: 1460-1469.

Lutovská B. 2012. Taxonomic comparison of Derby Eland and Common Eland (Taurotragus sp.) [MSc]. Prague: Czech University of Life Sciences Prague.

Lynch M, Conery J, Burger R. 1995. Mutation accumulation and the extinction of small populations. American Naturalist: 489-518.

MacCluer JW, VandeBerg JL, Read B, Ryder OA. 1986. Pedigree analysis by computer simulation. Zoo biology 5: 147-160.

Matthee C, Davis S. 2001. Molecular insights into the evolution of the family Bovidae: A nuclear DNA perspective. Molecular Biology and Evolution 18: 1220-1230.

McCaffree L. 2011. Eastern Giant Eland (*Taurotragus derbianus gigas*) International Studbook. Escondido: San Diego Zoo's Safari Park.

Merrell DJ. 1994. The Adaptive Seascape: The Mechanism of Evolution: University of Minnesota Press.

Milner JM, Nilsen EB, Andreassen HP. 2007. Demographic side effects of selective hunting in ungulates and carnivores. Conservation Biology 21: 36-47.

Müller DW, Lackey LB, Streich WJ, Fickel J, Hatt J-M, Clauss M. 2011. Mating system, feeding type and ex situ conservation effort determine life expectancy in captive ruminants. Proceedings of the Royal Society B: Biological Sciences 278: 2076-2080.

Pacifici M, Santini L, Di Marco M, Baisero D, Francucci L, Marasini G, Visconti P, Rondinini C. 2013. Generation length for mammals. Nature Conservation 5: 87-94: 7.

Perez-Enciso M, Fernando R. 1992. Genetic evaluation with uncertain parentage: a comparison of methods. Theoretical and Applied Genetics 84: 173-179.

Putman R, Apollonio M, Andersen R. 2011. Ungulate Management in Europe: Problems and Practices: Cambridge University Press.

Renaud P, Gueye M, Hejcmanová P, Antoninova M, Samb M. 2006. Inventaire aérien et terrestre de la faune et relevé des pressions au Parc National du Niokolo Koba. African Parks Network.

Rubes J, Kubickova S, Pagacova E, Cernohorska H, Di Berardino D, Antoninova M, Vahala J, Robinson TJ. 2008. Phylogenomic study of spiral-horned antelope by cross-species chromosome painting. Chromosome Research: Springer, p935-947.

Rudnick JA, Lacy RC. 2008. The impact of assumptions about founder relationships on the effectiveness of captive breeding strategies. Conservation genetics 9: 1439-1450.

Traylor-Holzer K. 2011. *PMx Users Manual, Version 1.0*. Apple Valley: IUCN SSC Conservation Breeding Specialist Group, p156.

WAZA. 2007. Giant eland (*Tragelaphus derbianus*). Available at http://www.waza.org/en/zoo/visit-the-zoo/giraffes-and-antelopes/antelopes-1256827903/tragelaphus-derbianus: Accessed 2014-02-02.

WAZA. 2011. ISIS/WAZA Studbook Library. Available at http://www.waza.org/en/site/conservation/international-studbooks/studbook-library: Accessed 2014-03-12.

Weisberg PJ, Thompson Hobbs N, Ellis JE, Coughenour MB. 2002. An ecosystem approach to population management of ungulates. Journal of Environmental Management 65: 181-197.

Williams BK, Nichols JD, Conroy MJ. 2002. Analysis and Management of Animal Populations: Modeling, Estimation, and Decision Making: Academic Press.