Research Article

Challenges for Captive Wild Mammals at Safari Zoo Lahore by Post-Mortal Analysis

Rida Ahmad[1]*, Zulfiqar Ali[1], Muhammad Azhar[2], Komel Ahmed[1], Zahra Hussain[1]

[1]Institute of Zoology, University of the Punjab, Lahore, Pakistan; [2]Safari Zoo, Lahore, Pakistan.

Abstract | Captive breeding is an important conservation tool. In recent years the number of mammals in captivity has increased significantly. Along with births, there are mortalities as well. Records are important for the assessment of birth and mortality rates of animals in captivity. The current study was conducted to estimate birth and mortality rates along with causes leading to death of mammals. For this purpose, records of different mammalian species were taken for past five years (2012-2016) from Safari Zoo Lahore. Data was obtained from stock position through frequent visits to the study site. Year wise data indicated that there was 25%, 20%, 20%, 17% and 18% birth rate in 2012, 2013, 2014, 2015 and 2016 respectively. While mortalities in respective years were 11%, 8%, 11%, 23% and 47%. Highest mortalities (47%) were recorded in 2016 due to viral and parasitic infections (malignant catarrhal fever) in mammals (Black buck). Study revealed that there was no age specific mortality rate in any species although variations exist among juvenile and adult stage. Gender based analysis revealed that in case of African lions there were higher mortalities in males than females. In ungulates, results showed that gender did not affect the death of an individual. Post mortem reports were obtained to get maximum information about the reasons of mortalities. According to post mortem reports it was concluded that most of the deaths were due to bacterial and viral diseases.

Received | September 27, 2021; **Accepted** | November 9, 2021; **Published** | June, 2022
***Correspondence** | Rida Ahmad, Institute of Zoology, University of the Punjab, Lahore, Pakistan
Email: ridaahmad411@gmail.com
Citation | Ahmad, R., Ali, Z., Azhar, M., Ahmed, K. and Hussain, Z. 2022. Challenges for Captive Wild Mammals at Safari Zoo Lahore by Post-Mortal Analysis. *Journal of Innovative Biology and Environmental Sciences*, *2*(1): 1-14
Keywords | Captivity, Birth, Mortality, Mammals, Survivorship curves, Safari Zoo Lahore

1. Introduction

Captive breeding is the act of allowing animal reproduction under controlled circumstances, away from their natural habitat, in farms, zoos, or other enclosed institutions. Humans decide which particular animals will be part of a captive breeding population and which animals will mate in that particular population. Creating a self-sustaining captive population is the main objective of the majority of captive breeding projects. Successful captive breeding program

provide zoos with animals for public display, reducing the need to gather them from the wild. Captive animals are used to educate zoo visitors about the need of biodiversity preservation and to pique the public's interest in conservation concerns. Captive breeding programs also have a significant educational benefit. Several scientific initiatives are supported by the animals kept in captive breeding programs. Several groups offer assistance with captive breeding and reintroduction initiatives (Ralls and Ballou, 2013). Many difficulties arise when wild animals are reproduced in captivity. As these populations are frequently tiny, long-term survival is fragile due to the possibility of random events (such as epidemics or natural disasters) as well as potential negative effects of the progressive loss of genetic variation (Pimm, 1991; Witzenberger and Hochkirch, 2011; Watt *et al*., 2021).

Researchers including veterinarians, zoologists and others may use captive breeding operations as a research platform to carry out studies that may improve understanding of the biology of a particular species. In order to test ecological and evolutionary theories and forecast future population size and structure for population control methods, estimates of wild animal mortality are crucial (Griffith *et al*., 2016). The objectives of present study were to assess possible causes of mortality in certain captive ungulates, Black buck, Chinkara, Hog deer, Spotted deer, Fallow deer, Mouflon sheep and Blue bull while, carnivores included African lions, through post-mortem examination. To date no such studies have been conducted to find out mortality rates of zoo animals in Pakistan. The objectives of this study were (i) to estimate the birth and mortality rates of mammals in captivity, (ii) to study age specific mortality rates and variations among different species, and (iii) to find out root causes of unnatural deaths.

2. Materials and Methods

2.1. Sampling site

The site selected for current study was Safari Zoo, Lahore. It is situated at a distance of about 32 km from Lahore City on Raiwind Road and 12 km from Thokar Niaz Baig Chowk (310 22'57 N, 740 12' 47 E and elevation 208m) in district Lahore, Punjab, Pakistan.

Safari zoo Lahore is constituted over an area of 250 acres. A beautiful dual way avenue (1.3 km) leads from Lahore Raiwind Road to the main gate/ entrance of Park. The climate of the area is moderate with minimum temperature occurring in the month of January and maximum in June/July. Annual average rain falls ranges "25.30". Most of the rain fall occurs during monsoon season. Soil is somewhat saline and canal water is always available for irrigation purposes.

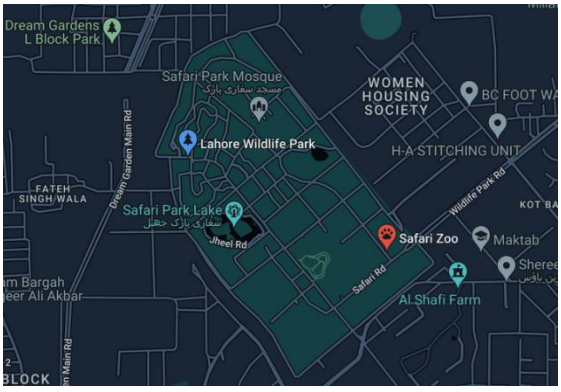

Figure 1: Map of Safari zoo Lahore

2.2. Number of Animals

Currently there are 18 species of mammals and 35 species of birds in Safari Zoo Lahore. Mammals include Black buck, Blue bull, Hog deer, Spotted deer, Mouflon sheep, Chinkara, Fallow deer, Zebra, Addax, White lion, Brown African lion, Brown tiger, Samber, Black jaguar, Puma and Black bear. The species which were selected for current study included the African lion, Black buck, Fallow deer, Hog deer, Spotted deer, Mouflon sheep, Blue bull and Chinkara. The data for

aforementioned species was collected and analysed.

2.3. Data Collection

Secondary data was collected from Safari Zoo Lahore through frequent visits. Approximately 2-3 visits were done per week for a total period of 5 months from November, 2016 to March, 2017 for the sake of data collection. Number of births and deaths along with their dates were noted from stock register. Data was based on stock position of previous five years.

Following information was of major concern through stock position:

- Numbers and dates of birth of concerned species for the previous five years
- Total numbers and dates of birth of concerned mammal species
- Total number of mortalities of concerned mammal species and dates of death
- Ages of dead animals
- Variations in birth and death rates of different species

A major objective of the study was causes of mammalian mortalities at study site. For that purpose, following points were considered.

- Post mortem reports of previous five years to determine reasons of death
- Interviews of officials and animal keepers for insight in to the management issues along with veterinary aspects
- Direct observation was made through frequent visits to know the condition of existing species
- Estimate the problems that could be the reason behind the mortalities of species in previous years

2.4. Interviews of Safari Zoo officials

Information about causes of death of concerned mammal species was gathered through interviews of Safari zoo officials, which included the supervisors and veterinary officers. Frequent visits were done for the confirmation and authentication of reasons/causes stated by officials and keepers.

2.5. Data Analysis

Life tables

To assess the mortality rates of concerned mammalian species, life tables were prepared. A life table is death schedule of a population. It shows the mortality rate experienced by each age group: the age specific death rate. There are two types of life tables.

1. Static life table
2. Dynamic life table

In current study static life tables were constructed. Static life tables are used to estimate the number of living individual at specific age at a particular point in time. In these tables it is assumed that mortality pattern would not have been changed previously over time, so that current population is showing same mortality pattern as before (Raees, 2011). Static life tables of recorded data of Safari Zoo Lahore were constructed to obtain survivorship curves and for estimation of age specific mortality rate of each species.

Survivorship curves

It is a graphical representation of death rates of a species calculated by a life table. Graph is created by plotting l_x (number of survivors at that age) on y-axis and age (x) on x-axis. It shows mortality pattern of species with time. It is the fraction of a population that survives from one age to the next. Survivorship curves are often used for comparison between the following:

1. Different populations of a species
2. Same species in wild and captivity
3. Male and female death in same species

Mortality curves

Mortality curves are drawn by plotting q_x (age-specific death rate/ fraction of population dying at each stage) against age. q_x is the ratio between d_x and I_x (Raees, 2011).

d_x: Deaths between age class (x) and x+1
I_x: Survivors at start of age class x
q_x: It is plotted to estimate the age at which mortalities are intense

Variation in mortality rate of different species at Safari Zoo Lahore was assessed by analyzing year wise births and deaths of each species.

3. Results

Current study was based on secondary data that included information from stock position, post mortem reports and interviews of Safari zoo staff. Data was compiled to check year wise birth, mortality rate, variations in birth and mortality rates of species, age specific mortalities in mammals and core reasons of species mortality based on post mortem reports and some direct observations through frequent visits. The major causes of death on the basis of postmortem reports were gut infections, trauma, bacterial infections and endo- as well as ecto-parasitic diseases.

3.1. Year wise birth and mortality

Panthera leo showed highest birth rate in 2011 and 2016, while there was no birth of African lions in 2013 and 2014. In 2012 there was an incident at Safari Zoo Lahore in which a male tiger killed her female when the female was released in outer paddock, after that all male and female carnivores (lions and tigers) were separated from each other. After two years, pairing of lions was done and four lion cubs were born in 2015. It can be estimated that African lions breed well in captivity as conditions are favorable for them at Safari (figure 2).

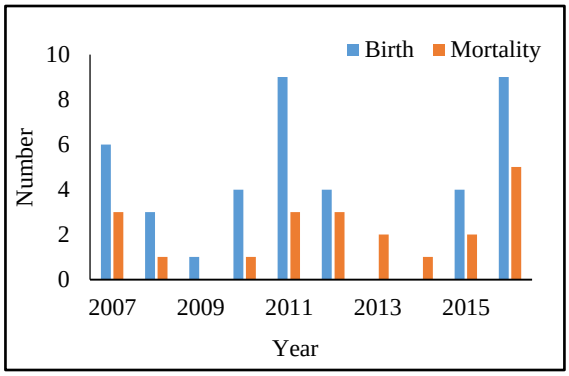

Figure 2: Year wise birth and mortality in African lions

Black buck survived well in captivity but mortality was recorded to be the highest in 2016 and lowest in 2012. In 2016, there was an outbreak of a viral disease (malignant catarrhal fever) which caused heavy mortality in the entire herd (figure 3). The highest numbers of births were recorded in 2012 while mortality was highest in 2016. There were neither births nor any mortality in 2013.

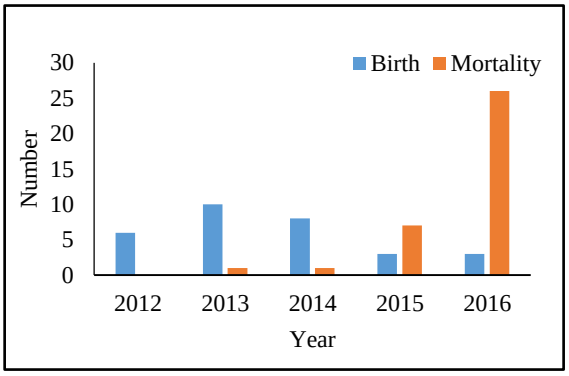

Figure 3: Year wise birth and mortality in Black buck

In hog deer the birth rate was more than the mortality rate (figure 4). Hog deer mainly died due to predatory attacks by inhabitant jackals and dogs which are free-ranging in Safari Zoo Lahore and entered the park due to broken boundary fence.

Spotted deer (figure 5) were the survivors in captivity at Safari Zoo Lahore. Birth rate of Chinkara was high in 2012 and 2013 while during 2014 to 2016 mortalities were more prominent. Diseases as well as some unknown reasons

contributed to these mortalities (figure 6).

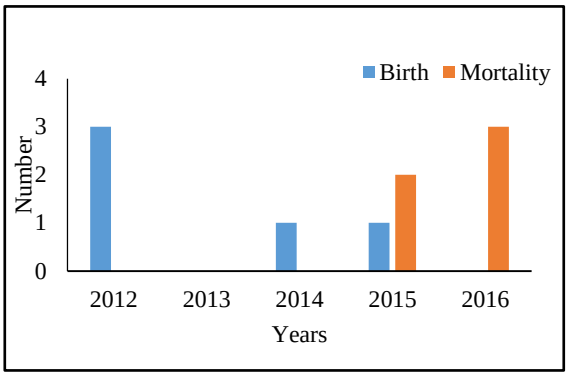

Figure 4: Year wise birth and mortality in Hog deer

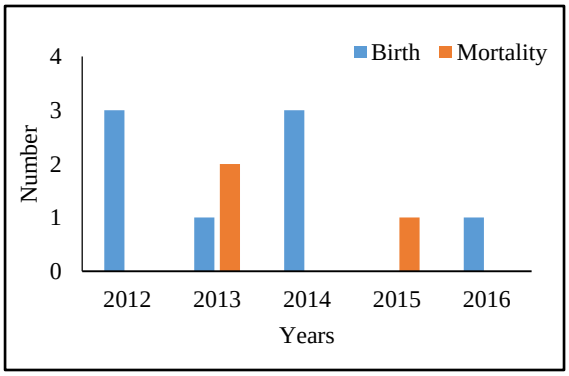

Figure 5: Year wise birth and mortality in Spotted deer

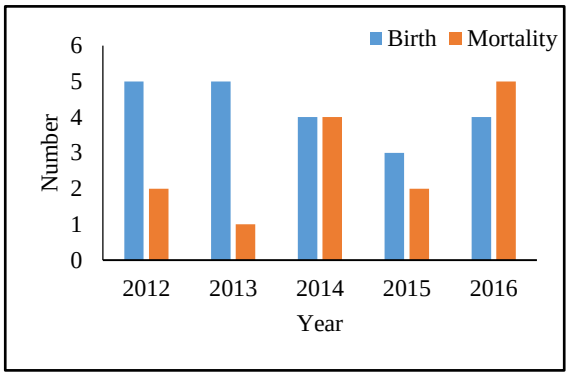

Figure 6: Year wise birth and mortality in Chinkara

There were only two mortalities of Mouflon sheep during past five years (figure 7). They died mainly due to disease. Birth rate was significantly higher than death rate in captivity. Blue bull showed highest birth in 2012 (figure 8). There was no birth in 2016 due to unavailability of male. There was no sufficient data of birth and death of fallow deer at study site.

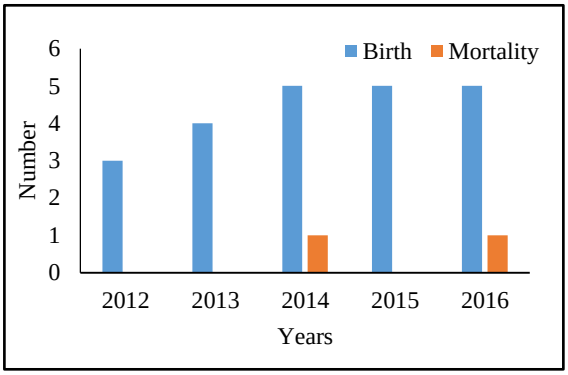

Figure 7: Year wise birth and mortality in Mouflon sheep

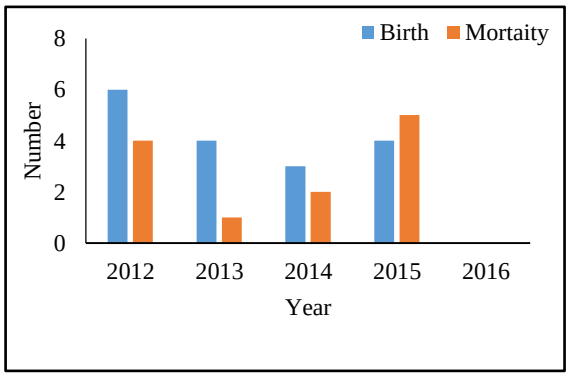

Figure 8: Year wise birth and mortality in Blue bull

Birth rates of each species vary greatly year wise. Progeny of all concerned species received in years 2012 to 2016 are presented in figure 9. The least births occurred in the year 2015. Based on available data birth rate of black buck was highest while lowest recorded births were of hog deer. Series of birth rate of different species can be written as:

Black buck > Mouflon sheep > Chinkara > African lion = Blue bull > Spotted deer > Hog deer

3.2. Mortality rates

Different species respond to captivity differently even under similar conditions. There are two ungulate moats at Safari Zoo Lahore. Chinkara, Black buck, Mouflon sheep and Blue bull are present

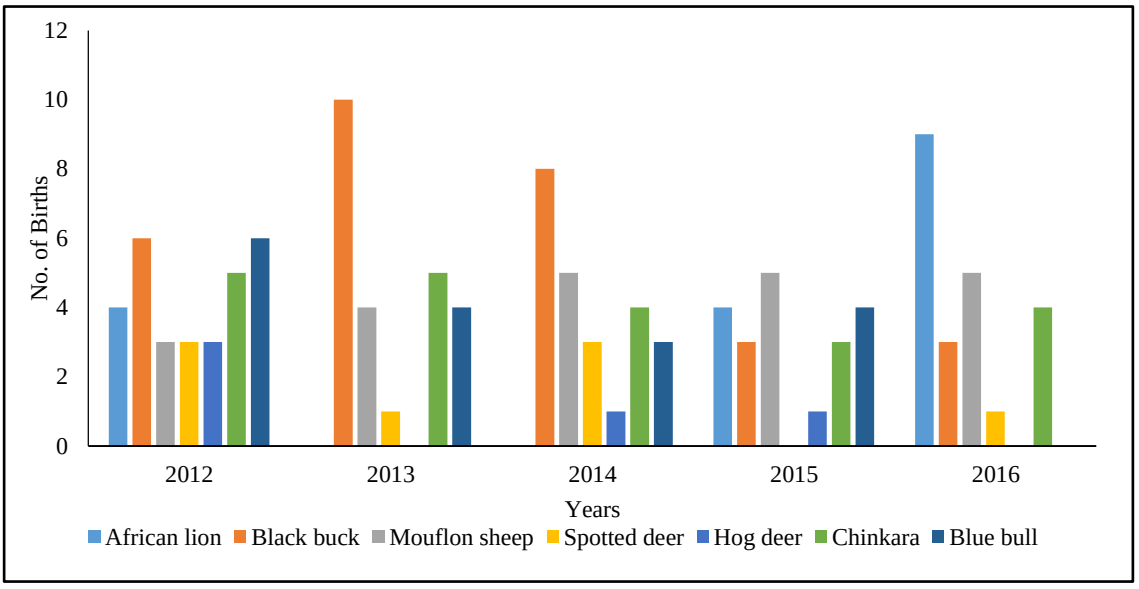

Figure 9: Year wise comparative birth of concerned mammals at Safari zoo Lahore

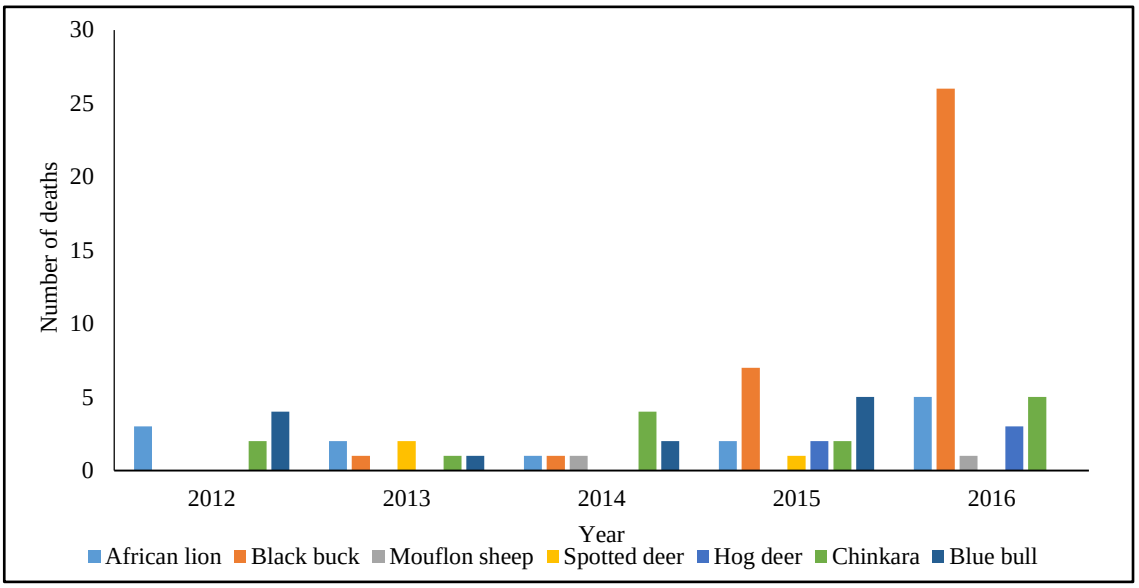

Figure 10: Year wise comparative birth of concerned mammals at Safari zoo Lahore

in one moat while Spotted deer, hog deer and Fallow deer were present in the other. Both moats are almost same in area cover and design. Even then species showed different mortality rates. There was highest mortality of black buck while least number of deaths occurred in mouflon sheep during past five years (figure 10). Series of mammalian death rate can be written as:

Black buck > Chinkara > African lion > Blue bull > Hog deer > Spotted deer > Mouflon sheep

3.3. Survivorship and Age specific mortality rates

Data of birth and death rate was analyzed. Life tables and survivorship curves were constructed for the estimation of age specific death rates of mammals (figure 11). Analysis of data collected from Safari showed that during past 10 years there were four still births of African lions. During first week, only a single mortality was recorded. From second week to one month of birth one death occurred. It was

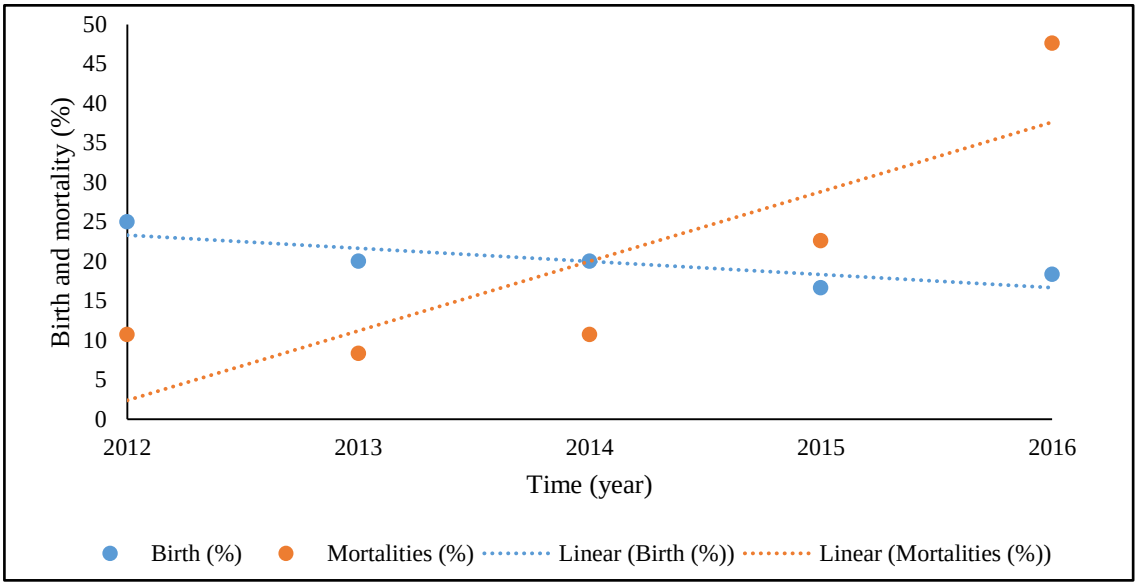

Figure 11: Year wise comparative birth of concerned mammals at Safari zoo Lahore

followed by 3 mortalities till first month of age. There highest number of mortalities occurred from second to eighth month, as there were 8 mortalities at this age. There were only two mortalities recorded from 9th month to one year. There were more deaths at infant and juvenile stage than sub adult age and adult hood. There was no age specific mortality rate in African lions. Although there was highest rate at still birth and second month of age (figure 12 & 13).

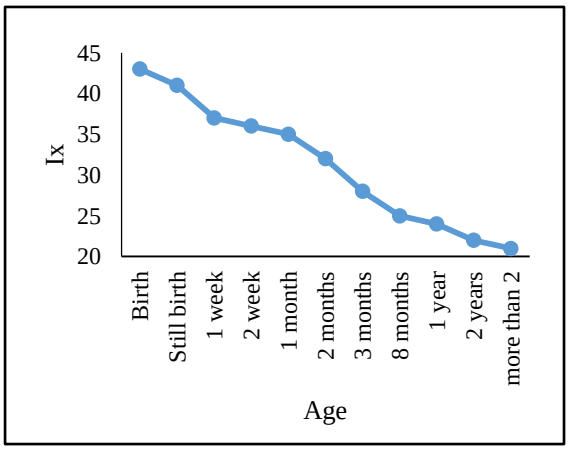

Figure 12: Survivorship curve of African lions

Minimum rate was recorded at first and second week after birth.

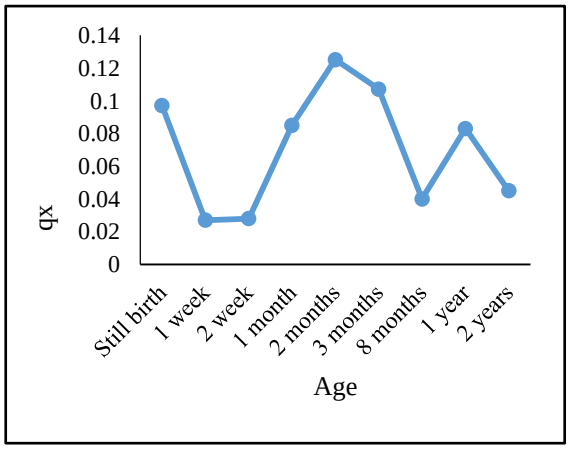

Figure 13: Age specific death rate of African lions

Black buck breeds well in captivity as well as it would in wild. They survive well at infant and juvenile stage. Only eight deaths have been recorded from birth to one year of age. Analysis of stock position showed that twenty mortalities had occurred during first and third year of age. Mortality rate of black buck was highest at two years of age (figure 14 & 15). There was no still birth recorded. A conclusion could not be drawn about age specific mortalities of this species because in 2016 a blood parasitic infection caused death of the entire herd. Only two sub adult individuals survived. On the basis of

previous record, before 2016 and those who survived in 2016, it can be concluded that black buck survived more at infant, juvenile, and sub adult stage. Death rate increased with age.

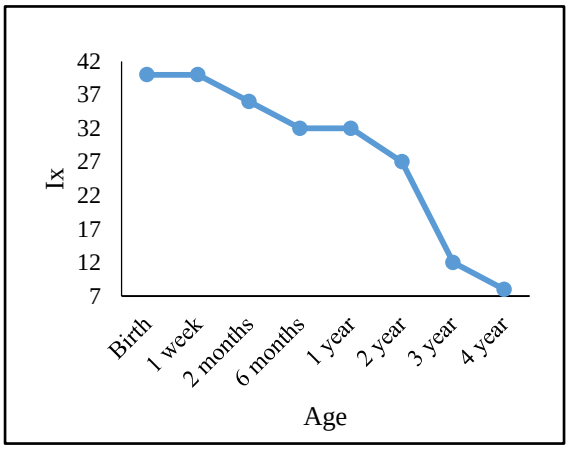

Figure 14: Survivorship curve of Black buck

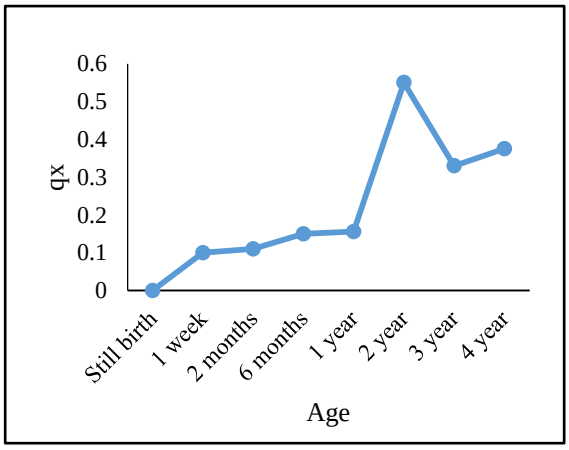

Figure 15: Age specific death rate of Black buck

Only one still birth has been recorded in hog deer in past five years (figure 16 & 17). Most of the deaths occurred at second year of age. Overall mortalities of hog deer were less than lion, black buck, chinkara and blue bull. According to data no death has been recorded at one and third year of age. As there were not much mortalities and according to post mortem reports these hog deer died due to diseases while one hog deer died due to predatory attack by dogs at night in the captive site, any statement about age specific mortalities cannot be reported.

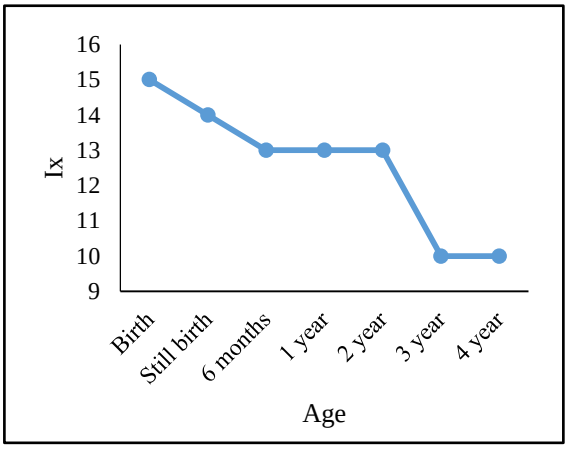

Figure 16: Survivorship curve of Hog deer

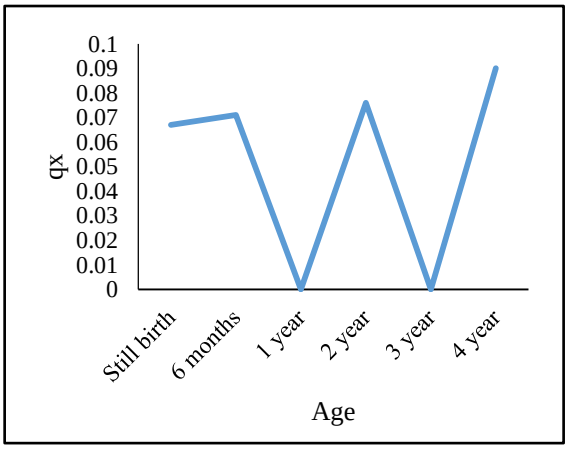

Figure 17: Age specific death rate of Hog deer

Only a few mortalities of spotted deer have been recorded. Only one still birth and a single mortality at four months of age were recorded. One female died at 4 years of age (figure 18 & 19).

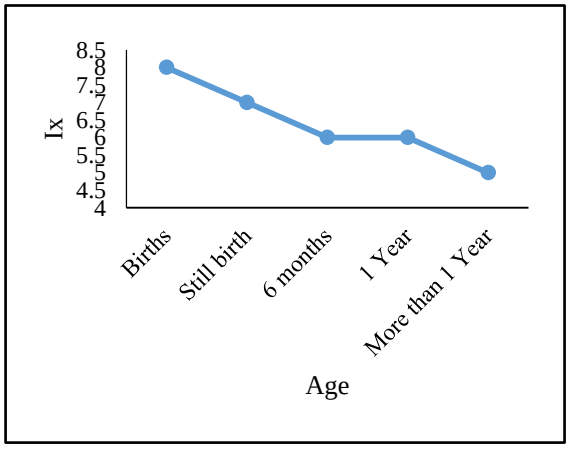

Figure 18: Survivorship curve of Spotted deer

There is no age specific death rate in spotted deer. Survival rate of spotted deer was high. Mortality rate was same at still birth, till six months, one and more than one year of age.

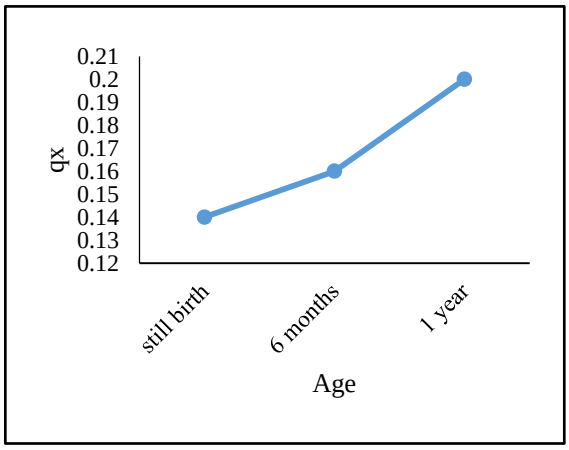

Figure 19: Age specific death rate of Spotted deer

Most of the mortalities in Chinkara have been recorded at juvenile stage. There were nine mortalities from birth to second month of age. Number of deaths decreased with age. Highest mortality rate of species was recorded at second month after birth. At age of 2-year mortality rate was zero. In case of Fallow deer and Blue bull, age of dead individual was not available, that is why life tables and survivorship curves for these species are unavailable.

Data was analyzed by SPSS 16.0 software. Mann-Whitney U test used to estimate the effect of gender on mortalities of ungulates. Results revealed that gender have non-significant effect on death of these mammals with Asymptotic *p*-value 0.624. Statistical analysis for African lions was not done due to small data size. There were 9 mortalities of males while 4 females died in captivity 2012 to 2016 years. Different causes of deaths in mammalian species have been listed in Table 1 (Annexure 1).

Officials as well keepers were interviewed for this study. According to officials and direct observations from numerous visits it was concluded that there are some reasons that had contributed to the mortalities of species along with diseases, which included early age natural mortalities, nursing rejection behavior of mothers. Area is also a major concern for carnivores. Breeding success of lions at Safari Zoo Lahore is good but there is less available space to keep the cubs immediately after birth. Keeper's negligence is also contributing factor to the deaths of mammals as they don't inform doctors about any unusual behavior of animals. They do not change water at proper time according to instructions. Management do not get proper budget at time for medicines.

4. Discussion

Present study has determined that there are many causes which might result in mortality in zoos, although not all of them occur in the wild. Certain animals are vulnerable to illnesses that are not often present in their natural settings, such as zoonotic infections spread by humans like tuberculosis. Moreover, some animal species pass away at a certain stage of their life cycles or as a normal outcome of actions like breeding (Frame, 2008).

Current study was conducted for the estimation of age specific, gender based and year wise mortality rate of selected mammals at Safari Zoo Lahore. Year wise data indicated that there was 25%, 20%, 20%, 17% and 18% birth rate in 2012, 2013, 2014, 2015 and 2016 respectively. While mortalities in respective years were 11%, 8%, 11%, 23% and 47%. Highest mortalities were recorded in 2016 due to viral and parasitic infections in mammals. There were average 13.45% mortalities in past five years (2012-2016). Naidu (2006) reported a 14.2% average death rate at the National Zoo in New Delhi. He also noted that the average death rate for animals at the Philadelphia Zoo dropped from 18.8% to 11% after the food was modified during

a 20-year period. Whereas, present study found that 35 fatalities of the same species have occurred in previous five years. Acharjyo and Rao (1987) recorded 83 black buck deaths in sixteen years (1967-1983). About 22 lions, 16 hog deer, 17 Nilgai, and 113 spotted deer were reported dead in the Nankandan Zoo, however in present study, 17 lions, 5 hog deer, 17 Nilgai, and 8 spotted deer perished (2012 to 2016).

Many factors contribute to zoo fatalities. There are several significant elements which must be taken into account. Inbreeding depression, high costs, domestication effects, disease breakout, and behavioral incompatibilities are only a few of the variables that contribute to the poor breeding success observed in captivity (Snyder *et al*., 1996; Akanbi *et al*., 2021). Although while animals kept in captivity are protected from predators, do not starve, and get medical attention (Watters, 2009), very few species that are bred in captivity are able to maintain constant reproduction and survivability. By comparing age-specific death rates between these two groups, Packer *et al.* (2013) looked specifically for a probable human influence signal. When compared to females in Hwange, those in the Serengeti had somewhat lower levels of prime-adult mortality, a similar level of senescent mortality, and greater initial cub mortality. They also observed a sharper fall in death rates across the newborn and juvenile periods (Barthold, 2016). When Kohler *et al*. (2006) studied 12 different species of carnivores, from African lions to fennec foxes (*Vulpes zerda*), they discovered that the average newborn death rate was 29% within the first week (*Panthera leo*). Moreover, mortality differed by gender. Male mortality in the Serengeti population was greater than female death at all ages (Barthold, 2016; McEvoy *et al*., 2021).

Present study revealed that the Black buck survived well in captivity but mortality was highest in 2016 and lowest in 2012. In 2016, there was outbreak of a viral disease (malignant catarrhal fever) in them which caused heavy mortality in whole herd. Other causes according to post mortem reports were heat shock strangulation in small intestine, traumatic injury, colic or impaction, corynebacterium pyogenes infection, bacterial toxemia, respiratory distress, hemorrhagic enteritis, bronchopneumonia, acute pneumonia and multiple chronic infections. There were more mortality rates in adults than infants and juveniles. According to Bhattachariya and Chattopadhyaya (1979), newborn fatalities made up 23-24% of the 34 total deaths, or 77-78%, in their study reported black buck and spotted deer mortality in the Ballavpur wildlife sanctuary. Fatalities from various forms of traumatic injuries were the leading cause of mortality among illnesses and pathological conditions identified in diverse species of ruminants: 179/380 (47.1%). Several other illnesses were noted, including fasciolosis (10/380, 2.6%), septicemia (9/380, 2.4%), pneumonia (7/380, 1.8%), hepatitis and cirrhosis (5/380, 1.3%), gastroenteritis (12/380, 3.2%), tuberculosis (22/380, 5.8%), and gastroenteritis (12/380, 3.2%). Hunger/weakness/anemia, stress, dystocia, splenic rupture, tetanus, ruminal impaction, and edoema in serous cavities are conditions similar to the current research study, and are in accordance with concurrent findings by Sharma *et al*. (2014). According to Acharjyo and Rao (1987), gastroenteritis caused 15 fatalities of wild ruminants kept in captivity. Due to the fact that these animals are restricted to the same area and there is a constant risk of feces contaminating food, verminous gastroenteritis in wild ruminants appears to be significant. Similar difficulties include pin-pointing specific positive instances and effectively deworming these species. When mass deworming is necessary, it is

not always practicable to provide the correct medication with the right dosage.

5. Conclusion

It was concluded from the results that there was no age specific mortality rate found in captive mammals at Safari zoo Lahore. Although in African lions and Chinkara higher mortality in infants and juveniles were recorded, whereas in Black bucks adults exhibited higher mortality. Gender based analysis has showed that in African lions, female mortality rates are less than captive males, however in angulates there is no significant effect of gender on their death. There were different causes of death of captive wild mammals that included diseases, trauma, stress, shock and some causes remained unidentified.

6. Acknowledgments

Authors acknowledge the contribution of the management at Safari zoo Lahore.

7. Author's Contribution

Ahmad, R. and Ali, Z. conceptualized the study. Ahmad, R., Ahmad, K. and Hussain, Z. collected the data. Ahmad, R. and Azhar, M. compiled the data. Ahmad, R., Ahmad, K. and Hussain, Z. drafted the manuscript. Ali, Z. reviewed and improved the manuscript.

8. Conflict of Interest

There is no conflict of interest.

9. Novelty Statement

The data will provide useful information about status of disease condition causing mortality along with their rates based on age and gender. It would be helpful in the development of veterinary protocols for healthy breeding of wild animals in captivity.

10. References

Akanbi, O.B., Jegede, H.O., Adam, M., Oludairo, O.O., Aiyedun, J.O., Rimfa, A.G., Ahmed, J., Barde, I.J., Hanga, A.B., Ajadi, A.A. and Atata, J.A., 2021. Disease and mortalities in selected zoological gardens in Nigeria. *Comparative Clinical Pathology*, *30*(5), pp.743-753.

Barthold, J.A., Loveridge, A.J., Macdonald, D.W., Packer, C. and Colchero, F., 2016. Bayesian estimates of male and female African lion mortality for future use in population management. *Journal of Applied Ecology*, *53*(2), pp.295-304.

Bhattacharya, T., Chattopadhyay, B. and Chattopadhyay, B.N., 1979. Population status of Indian Blackbuck (*Antilope cervicapra* Linn.) and spotted deer (*Axis axis* Erxleben) in Bal· lavpur wildlife sanctuary, West Bengal. *Journal of Wildlife Preservation Society of India*, 20, p.39.

Gaurav, S., Kamalakannan, M., Dam, D. and Akhlaq, H., 2014. *Status and conservation of mammalian diversity in Indian Himalaya*. In Biological Forum (Vol. 6, No. 2, pp. 273-299). Satya Prakashan.

Griffith, A.B., Salguero-Gómez, R., Merow, C. and McMahon, S., 2016. Demography beyond the population. *Journal of Ecology*, *104*(2), pp.271-280.

Kohler, I.V., Preston, S.H. and Lackey, L.B., 2006. Comparative mortality levels among selected species of captive animals. *Demographic research*, *15*, pp.413-434.

McEvoy, O.K., Ferreira, S.M. and Parker, D.M., 2021. The influence of

population demographics on lion (*Panthera leo*) growth rates in small, fenced wildlife reserves. *African Journal of Wildlife Research*, *51*(1), pp.75-89.

Packer, C., Loveridge, A., Canney, S., Caro, T., Garnett, S.T., Pfeifer, M., Zander, K.K., Swanson, A., MacNulty, D., Balme, G. and Bauer, H., 2013. Conserving large carnivores: dollars and fence. *Ecology letters*, *16*(5), pp.635-641.

Pimm, S.L., 1991. *The balance of nature?: ecological issues in the conservation of species and communities*. University of Chicago Press.

Raees, P.A., 2011. *An introduction to zoo biology and management*. Wiley Blackwell, West Sussex, UK.

Ralls, K. and Ballou J.D. 2013. *Captive Breeding and Reintroduction*. 2nd ed., In: Encyclopedia of Biodiversity, (Ed. Levin, S.A.) Vol. 1: 662-667. Academic Press. Ranjitsinh, M.K., 1989. The Indian blackbuck. Natraj Publishers, Dehradun.

Rathore, B.S. and Khera, S.S. 1979. *Mortality in tigers in India*. Paper presented in 1st International Symposium on tiger. New Delhi.

Schaller, G.B., 1967. *The deer and the tiger*. The University of Chicago press, Chicago pp. 54-236. Street, Philip: Animals in captivity. Faber and Faber, London, pp. 78-218.

Snyder, N.F., Derrickson, S.R., Beissinger, S.R., Wiley, J.W., Smith, T.B., Toone, W.D. and Miller, B., 1996. Limitations of captive breeding in endangered species recovery. *Conservation biology*, *10*(2), pp.338-348.

Watt, A.M., Marcec-Greaves, R., Hinkson, K.M., Poo, S., Roberts, B. and Pitcher, T.E., 2021. Effects of age on sperm quality metrics in endangered Mississippi gopher frogs (Lithobates sevosus) from captive populations used for controlled propagation and reintroduction efforts. *Zoo Biology*, *40*(3), pp.218-226.

Witzenberger, K.A. and Hochkirch, A., 2011. Ex situ conservation genetics: a review of molecular studies on the genetic consequences of captive breeding programmes for endangered animal species. *Biodiversity and conservation*, *20*, pp.1843-1861.

Annexure 1

Table 1: Causes of mortalities of different species based on post mortem reports

Species	Cause of Death	sex
Black buck	Heat Shock	Female
	Strangulation in Small Intestine	Female
	Traumatic Injury	Female
	Colic or Impaction	Female
	Corynebacterium pyogenes infection, bacterial toxemia	Female
	Respiratory Distress	Female
	Hemorrhagic enteritis	Female
	Malignant catarrhal fever infection	Male + Female
	Bronchopneumonia	Male
	Acute Pneumonia	Male
	Multiple Chronic infections	Male
Fallow deer	Respiratory distress	Female
	Shock	Female
Spotted deer	Pulmonary edema	Female
Mouflon sheep	Hypovolemic shock	Male
Hog deer	Pleurisy with internal bleeding in cavity	Male
	Bronchopneumonia	Male
	Hemorrhagic enteritis	Male
	Tuberculosis	Female
	Shock	Female
Chinkara	Traumatic injury	Female
	Respiratory distress due to lungs failure	Female
	Pulmonary edema and congestion in abomasum	Female
	Pulmonary failure	Female
	Bronchopneumonia	Female
	Hemorrhage enteritis	Male
	Heart Failure	Male
	Pulmonary hemorrhage and Congestion	Unknown
Blue bull	Internal Blood loss following rupture of Placenta	Female
	Hepatic cirrhosis	Female
	Caseous necrosis and pulmonary hemorrhage	Female
	Respiratory distress due to lungs failure	Male
	Constipation and gastric impaction	un known
	Pre-mature birth	---
Lion	Bacterial septicemia and Toxemia	Female
	Anemia and acute hepatic necrosis	Female
	Endo-toxic shock	Female
	Anemia and peritonitis	Female
	Asphyxia	Male
	Hypo-volumic shock and Aneurysm	Male
	Septicemic Shock	Male

Species	Cause of Death	sex
	Fibrinous pericarditis	Male
	Heart Failure	Male