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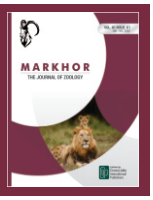

Original Article

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Survival and Behavioral Outcomes of African Lion (*Panthera leo*) Cubs Raised Under Three Management Conditions

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ABSTRACT

Understanding the effects of early-life rearing environments on survival and behavior is important for improving the welfare and management of captive and wild carnivores. **Objectives:** To compare the survival and behavioural development of African lion (*Panthera leo*) cubs raised under three rearing conditions to test how early-life management influences neonatal survival and welfare. **Methods:** This was a descriptive cohort study that monitored the litters of free-ranging area (Group A, n=7), maternal rearing under controlled zoo management (Group B, n= 5), and hand-reared (Group C, n=7) in Safari Zoo, Lahore, during 2022-2024. The measured outcomes were the survival rate of cubs up to 90 days of age, reasons for death (if any), the observation of aggression, play, and allogrooming, and health-related interventions, including illnesses and veterinary treatments. Veterinary examinations recorded health, and targeted animal sampling was used to gather behavioural data. There was no formal hypothesis testing, and the analysis was descriptive (counts, percentages, and rates). **Results:** Group A had a 3/7 (42.9%) survival rate to 90 days, whereas Groups B (5/5) and C (7/7) had a 100% survival rate. Different groups of Cubs raised in the wild showed differing degrees of aggressiveness, but behavioural results were not statistically analyzed. Early respiratory and gastrointestinal problems in hand-reared cubs were addressed by veterinary treatment, ensuring their complete survival. **Conclusions:** Several co-occurring factors, including veterinary care, diet, cleanliness, and environmental management, may contribute to the improved survival seen in managed groups, making it challenging to determine the impact of any one aspect.

INTRODUCTION

Recent genetic analysis recognizes two subspecies of lions, *Panthera leo* in central and western Africa and India, and *Panthera leo melanochaita* in southern and eastern Africa [1]. Lions are Vulnerable (IUCN A2c) in all parts of the world due to a decreasing trend in population. The major threats facing lion populations are trophy hunting, illegal trafficking, human-wildlife conflict, habitat destruction, and depletion of prey [2, 3]. Lions, being a keystone species, with slow reproduction rates, high spatial demands, and extremely small populations, are prone to changes in the environment [4]. Therefore, ex-situ conservation can gain even more significance [5]. The African lion is among the most widespread animals found in zoos worldwide [6], which explains the necessity to manage it properly and create the tools of welfare assessment [7]. In captivity, lions normally give birth to young ones every year, whereas in the wild, the average is once every two years. Captive African lions have a life expectancy of 25 years, although in the wild, they usually live between 8 and 10 years [8]. It is known that the reproductive success of African lions in captivity is affected by several biological and ecological variables; in general, the breeding success of the lions held in managed care has been relatively successful [9]. Nonetheless, the

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mortality of cubs is a danger in captivity and in the wild. Uncontrolled cubs can die due to lack of food, cannibalism, disease, and predation [10, 11]. Lioness infanticide has been reported to occur during periods of stress and hunger, and maternal rejection has also been cited as the cause of death in captivity [12]. These dangers emphasize how crucial it is to comprehend successful cub-rearing techniques. There are also certain circumstances when newborn lion cubs have to be hand-reared in captivity, which can be permanent. In situations where maternal care is lacking, hand-rearing lion cubs is difficult yet necessary. It helps manage endangered populations that are housed in captivity, especially for animals that have extended reproductive intervals or only produce one young annually [12]. Cub behaviour is also influenced by early rearing circumstances. The habitat that cubs raised in the wild encounter differs greatly from that of cubs raised by people. In fact, under similar findings, one research discovered that lion cubs of captive origin spent more time sleeping and less time active [13]. Activity budget comparisons suggest that the behavioural patterns of captive-origin lions may be different from those of wild prides [14]. However, because most behavioural studies of lions in the field concentrate on adult animals, there is a dearth of comprehensive literature on the activity budgets of wild lion pups [13]. In Pakistan and other countries, research on the behaviour and care of captive lions is growing. Some studies look at the behaviour [15, 16], breeding and mortality [17], and hand-rearing practices [18] of captive lions.

However, there are very few comparative studies that look at how various rearing circumstances impact cub survival and behaviour. In order to address this, this study aims to compare the behavioural development and survival rates of lion cubs raised in three different environments. This will close a research gap on the impact of early rearing environments on the welfare of lion cubs and their conservation prospects.

METHODS

Three sets of litters born in 2022–2024 at the Safari Zoo in Lahore, Pakistan, provided the data for this descriptive cohort study. Based on the raising conditions, each cub was assigned to one of the three groups (Groups A, B, and C). Other than standard husbandry, there was no further experimentation. Each group's data was gathered in a common management setting. As part of the regular operations at Safari Zoo Lahore, the cubs in Groups B and C were tested. Group A, on the other hand, consisted of cubs raised in a wildlife zone where they were allowed to explore the natural world. In addition to comprehensive observational recordings of the aggressive and social behaviours of cubs, survival data were gathered from birth until weaning. Regular veterinary examinations were also conducted to determine the health of every cube. This paper gives a preliminary comparison of survivorship and behaviour development of African lion cubs reared in three conditions; though, due to the small sample size, the study lacks statistical power and generalizability, and results should be viewed with caution. The entire procedures were performed following the guidelines of animal care in the institution, but the ethical explanation of the necessity to hand-rear animals, separate them early in life, and the intervention measures must be thoroughly addressed concerning the animal welfare requirements. The experiment involved six adult lionesses (two of each group), all of which were found to give birth to a litter during the course of the study. In Group A (wilderness), lionesses had four and three cubs, with a total of seven cubs. Group B consisted of five cubs (supervised maternal care) of two lioness litters, three and two cubs. Finally, in Group C (hand-rearing), there were 7 cubs in total, of two lionesses who gave birth to four and three cubs. Zoo staff had to hand-raise all seven cubes. Groups B and C showed 100% observed survival; however, very small sample sizes (n=5–7) may lead to overestimation, and these findings should be interpreted cautiously without strong comparative conclusions. Altogether, the three groups comprised 7, 5, and 7 cubs, respectively. All available cubs were included, representing a convenience sample, and no prior sample size calculation was performed, limiting statistical power. Group A - Wilderness (unassisted): In this group, females gave birth to and raised their cubs in the wild. Cubs nursed, interacted, and grew up with their mothers at all times and were not bottle-fed, while still being exposed to the environmental variability, such as temperature changes, parasites, and injuries, but without the presence of a daily routine that included a veterinarian. The management staff had no involvement with the cubs. We used this setting as the closest approximation to a natural baseline. Free-ranging enclosure: females raised cubs with minimal human intervention within a managed safari environment, which may not fully represent true wilderness conditions. Group B - Supervised Maternal Care: In this case, the lionesses still served as mothers for nursing and social rearing, but births took place in a zoo enclosure. The cubs stayed together with their litter and were given enrichment to encourage their behavioural development. However, the litter was closely supervised. The cubs were also regularly weighed and checked up on by the veterinarian. Routine preventive care was provided to the cubs, such as deworming and vaccinations, since this is the policy of the zoo. The cubs were treated immediately in case they displayed the initial signs of illness. Group C - Hand-Reared: In Group C, cubs were taken away from their mother at the few initial days after delivery and were hand-reared by the zoo personnel. At Safari Zoo, Lahore and in bottle-fed

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brood chambers, we kept newborn cubs and fed them a commercial milk replacer. The first volume of milk was about 10-12% of body weight during the first week which was increased to 18- 20% of body weight as they grew [6]. Cubs were fed eight times daily during the first 2 weeks, and the number of feeds was decreased to six times daily till they were 45 days of age. At the age of 45 days, they received moist food (chicken mince with milk), which was substituted by a meat diet at the age of 3 months. Hand-rearing was done under strict hygiene conditions, such as the sterilization of feeding equipment and brooder after each session. Whenever feasible, littermates were kept together so as to have social contact and so as to lessen the chances of isolation. Each cub was given survival status (90 days postnatal, yes/no). Cause of mortality (where applicable) was mentioned (e.g., infection, trauma). The number of cubs that survived to 90 days was divided by the number born to calculate the survival rate. Cubs were followed between the age of 4-12 weeks. The sampling technique employed in this study was the focal animal sampling in scoring aggressive and social behavior [19]. The researcher viewed any growling, snapping, swiping, or biting of either conspecifics or humans as aggressive behavior. The researcher put a mark on the frequency of aggressive acts per hour per cub. Social behavior (play and allogrooming) was also observed. Observers recorded behavioral data using standardized protocols; however, complete blinding to group assignments was not feasible due to visible differences in rearing conditions, which may introduce observer bias. Each cub was examined by a veterinarian twice a week. Any illness was noted. Any treatment given was monitored so that each litter received equal care.

Data were recorded on a standard data sheet and verified. Quantitative data (e.g., numbers survived, aggressive behavior) were described. No statistical analysis was conducted, since this was a descriptive report of selected litters. The methodological framework followed in this study is summarized (Figure 1).

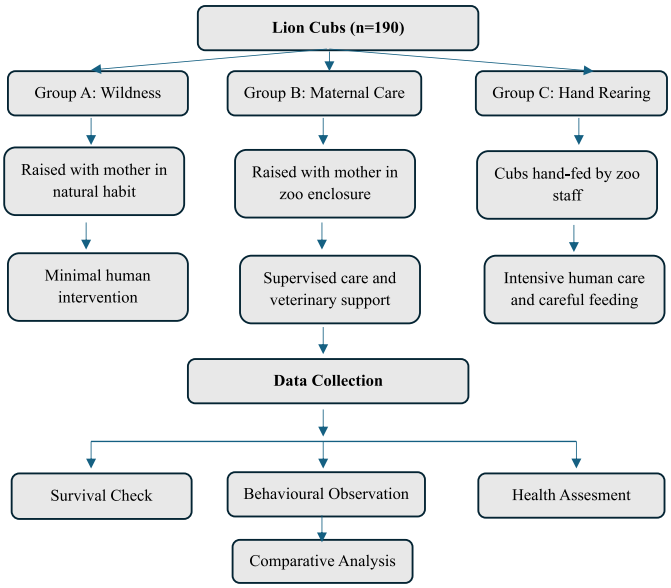

Figure 1: The Study Design Used for Evaluating Lion Cub Survival and Behavioural Outcomes Under Different Rearing Conditions

RESULTS

The survival rates differed across the three study groups. However, no formal hypothesis testing was performed, and therefore, no statistical significance can be inferred. Group A (Wilderness) had seven cubs born, with only three surviving, and this means that the survival rate was 42.9%. Deaths among them were comparatively high and were mostly due to infections and physical injuries, either because of the lack of medical treatment or environmental stress factors. Group B (Supervised Maternal care), in contrast, demonstrated significantly better results. All 5 cubs survived the period of study, giving a success rate of 100 percent. Constant maternal attention with frequent vet checkups seemed to be of great importance in minimizing deaths and enhancing healthy growth. The most successful survival was Group C (Hand-Reared in Safari Zoo). Seven cubs that were born under the controlled hand-rearing conditions also survived, which is equal to 100 percent (Figure 2).

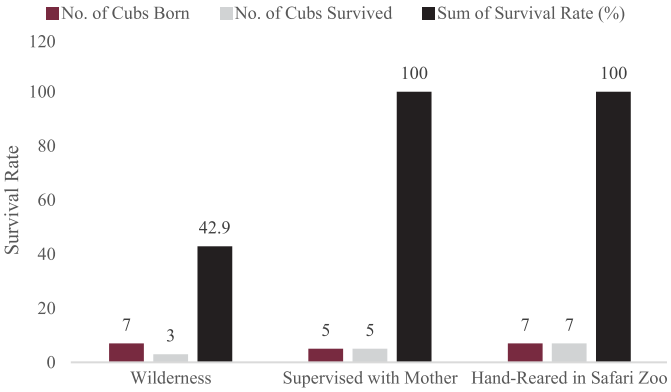

Figure 2: Survival Rate of Lion Cubs Reared in Different Conditions

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The behavioral evaluation demonstrated that there was an observed difference in the level of aggression in cubs raised in varying environmental conditions. Group A (Wilderness): Cubs had the highest levels of aggressive behavior. This was especially clear in the only surviving cub in the second litter that exhibited increased defensive and reactive behavior in comparison to the cubs in the other groups. This high level of aggression could be the behavior of a survival instinct in the absence of control within the wild. Group B (Supervised with Mother): cubs were moderately aggressive. Even though the defensive or territorial behaviors were observed occasionally, the cubs were relatively easy to handle. Maternal care in association with human supervision was found to tone down extreme responses in behavior without the loss of instincts. On the other hand, Group C (Hand-Reared in Safari Zoo) showed the least aggression. The cubs were of a quieter temper and readily adjusted to normal human contact and restriction of human hands. This would imply that behavior development would be greatly influenced by exposure to environmental factors in the early years of life and consistent conditions of caregiving (Table 1).

Table 1: Comparative Aggression Level Among Cubs Under Different Rearing Conditions

Groups	Rearing Conditions	Observed Aggression Level	Behavioral Traits
A	Wilderness	High	Defensive, reactive, heightened survival response
B	Supervised with Mother	Moderate	Occasional defensive behavior is manageable
C	Hand-Reared in a Safari Zoo	Low	Docile, adaptive to human interactions

Group C cubs had a number of health-related problems in the early stages of their development. The most common ones were the gastrointestinal problems (constipation and diarrhea), the cases of hyperthermia, and respiratory infections. The cause of these health complications was mainly in early life physiological instability and lack of natural maternal care. All the affected cubs, however, responded well to timely veterinary interventions, nutrition, vaccination, and hygiene care. This led to the survival of all hand-reared cubs, emphasizing the importance of systematic care and monitoring (Table 2).

Table 2: Health Management Practices and Veterinary Interventions Applied During the Hand-Rearing of African Lion Cubs

Health Management Aspects	Procedure / Treatment	Purposes
Veterinary Monitoring	Continuous supervision by the veterinary team	Ensure health and early detection of problems
Deworming	Administered regularly according to schedule	Prevention of parasitic infections
Vaccination	Routine feline vaccination program	Protection against infectious diseases
Constipation Treatment	Glycerine suppositories and Laxoberon syrup	Relief of digestive obstruction
Diarrhea Management	Reduced milk volume and probiotics administration	Correction of overfeeding- related digestive disturbance
Eye Care	Daily cleaning with sterile saline	Prevention of conjunctivitis and eye infections
Mineral Supplementation	Calcium and phosphorus supplements	Prevention of nutritional deficiencies and skeletal problems
Vitamin Supplementation	Multivitamin and mineral complexes	Support overall growth and development
Dosage Regulation	Adjusted according to cub age and weight under veterinary supervision	Ensure safe and appropriate supplementation

The death rate was higher for cubs reared in the wild. Because the environment was regulated, cubs raised by hand after receiving supervised maternal care had the best survival rate of 100%. These results suggest that supervised hand-rearing can significantly improve neonatal survival rates with veterinarian supervision, scheduled feeding, and sanitary practices. Conservation-wise, hand-rearing may be used as a good method of captive breeding and rehabilitation efforts, especially where cubs are threatened in the wild. Although wild-reared cubs are more aggressive compared to hand-reared cubs, the latter are more docile, and this characteristic can be useful in conservation breeding programs and reintroduction.

DISCUSSION

The current research indicated that there were significant variations in the survival and behavior of lion cubs reared under varying conditions. Cubs that had entirely grown in the wild exhibited the highest death rates, whilst those that had been reared with the monitoring maternal attention or hand-reared in a controlled environment recorded 100 percent survivability. These results are in line with the prior literature that has found better survival in controlled captive environments, but a more critical comparison with the recent literature is needed to put these results into perspective to identify the similarities and differences in the survival and behavioral outcome. It is a trend that is also found among other conservation and rehabilitation programs. There is extensive literature on the high mortality of large carnivore young ones and juveniles. As an illustration, the survival of Panthera pardus cubs during the first year was reported as less than 75 percent, which shows weak resistance to disease, predation, and environmental stress [20]. Such results confirm the high death rates of lion cubs brought up in the wild. Comparative analyses of ex situ populations in modern zoological institutions report substantial improvements in the survival of captive-born big cats, largely due to advances in husbandry, nutrition, veterinary care, and enrichment [21]. Another recent meta-analysis of Panthera species also discovered that cubs born in accredited zoos have greater

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first-year survival and extended lifespan [22]. Monitored feeding is a means to secure proper nutrition for the neonates. Cubs grow better with age-appropriate milk replacers and regularly spaced feeding, which is a method of preventing starvation in captive felids. The same was indicated in *Panthera leo persica* and other rescued neonates. Veterinary treatment and hygiene control at an early stage also improve survival, as it minimizes exposure to pathogens and environmental stress in confinement centers. In line with this, a longitudinal study of *Panthera leo* populations revealed an average cub mortality of about 28.4 with a lower mortality rate of 20.5 in cubs born to mothers in their natal facility compared to cubs whose mothers were transferred (43.7%) [11]. The level of aggression was greater in wild-reared cubs, which might have been adaptive to environmental stresses and life pressure. On the other hand, hand-reared cubs were quite submissive and could even be handled by humans. These results are in line with prior research showing that regular human exposure tames innate fear reactions (tameness) [23]. Programs for conservation breeding must achieve a balance between manageability and the preservation of behaviours necessary for survival in natural settings. Therefore, conservation breeding efforts need to strike a balance between manageability and the preservation of behaviours necessary for survival in natural settings. These results have significant implications for conservation. Hand-rearing can help with captive breeding programs and wildlife rehabilitation, especially for orphaned or rejected newborns or those in danger from parental neglect or predation. In addition to supporting ex-situ conservation objectives, structured hand-rearing contributes to population stability. However, there are ethical and ecological concerns. As noted in criticisms of the current lion farming fad [24], captive breeding and hand-rearing must prioritize animal welfare and prevent techniques that render lions less suited to be returned to the wild or encourage commercial exploitation.

The study's shortcomings include a limited sample size, a lack of statistical analysis, and the potential for confounding by many management factors concurrently. Because full blinding was not used, the behaviour assessments were observational and hence susceptible to bias. As a result, the results can be considered exploratory, and more study with bigger sample sizes and higher statistical power is advised. Furthermore, the study was conducted in a single institution, and different institutions may have different management approaches. Larger sample numbers, multi-institutional data, quantitative behavioural measurements, and statistically significant analysis are all necessary for future research to be reliable and develop best practices. It was only analyzed using descriptive statistics; instead, the analysis of future research should include proper statistical tests (e.g., Fisher's exact test, non-parametric tests) to make comparative interpretations.

CONCLUSIONS

The results demonstrate how important early-life care is in determining African lion cub survival and behavioural development. The high death rate in the raising environment was symptomatic of the weak cubs in the early growth stage, even though natural rearing is more typical of the actual ecological situation. On the other hand, the survival rates were considerably increased in the hand-reared animals under the supervision of a veterinarian. The findings suggest that organized management and improved survival outcomes may be correlated, but because the study is descriptive in nature, causal implications cannot be drawn. However, the behavioural differences across groups suggest that natural behavioural expression may be impacted by high-level human intervention. Therefore, to enhance long-term welfare, conservation and captive management initiatives must simultaneously aim to improve survival and maintain species-typical behaviours.

Authors' Contribution

Conceptualization: BNK
Methodology: MN, MT, FA, SNF, MRK, MNK
Formal analysis: AU, MN, MT, FA, SNF, MNK
Writing and Drafting: AU, MN, MT, FA, SNF, MNK
Review and Editing: AU, MN, MT, FA, SNF, MRK, MNK

All authors approved the final manuscript and take responsibility for the integrity of the work.

Conflicts of Interest

All the authors declare no conflict of interest.

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