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A review on behaviour and health condition of Manipur brow-antlered deer (*Rucervus eldii eldii*) for sustainable management and conservation in an *Ex situ* environment

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Abstract
Central Zoo Authority of India has listed Manipur Brow-antlered deer under the Conservation Breeding Programme in order to restore its population in several Indian zoological gardens. Some studies have been done regarding behaviour and health condition of Manipur Brow-antlered deer and related species in the wild or in captivity. But, there still remain many gaps in the behavioural studies and health status of this species. In future, more extensive research should be done in the field of conservation and management in an *ex situ* environment so that comparatively better captive environment can be established. This review paper revealed that for a successful captive breeding, a thorough knowledge of deer's behaviour and its health condition is necessarily required. It will also help to perpetuate sustainable growth and development of Manipur Brow-antlered deer which can be available to establish new populations in an alternative or natural habitat.

Keywords: manipur brow-antlered deer, behaviour, health condition, captivity

1. Introduction
The Manipur Brow-antlered deer *(Rucervus eldii eldii)* is recognized as an "Endangered" under The IUCN Red List of Threatened Species (Gray *et al*. 2015) [24] which is having the highest list of protection under the Schedule I of the Indian Wildlife (Protection) Act, 1972. Locally known as Sangai, is the Indian form of four sub species of Eld's deer. The other three sub species are *Rucervus eldii thamin* in central plains of Myanmar and western Thailand, *Rucervus eldii siamensis* in Lao PDR and in the northern and eastern Cambodia and a fourth sub species *Rucervus eldii hainanus* in Hainan's Island China. In India, it is referred as Manipur Brow-antlered deer or Sangai with its zoological name as *Rucervus eldii eldii* (McClelland 1842; Wilson and Reeder 2005; Timmins and Duckworth 2008) [43, 75, 68]. This rare, endemic and endangered sub species shows its confined distribution only in the State of Manipur (Whitehead 1972; Hussain *et al*. 2006) [74, 32]. Indian Zoological Gardens, currently managing 211 Brow-antlered deer are trying their best to maintain a viable and stable population in captivity. Still, there exists the need of more scientific and well-planned management strategies for maintaining a sustained population in captivity. According to Population and Viability Assessment (PHVA 1992) [55] captive as well as wild populations of this species are seriously at risk.

In order to increase sustainability and security of the Manipur Brow-antlered deer population in zoos, better understanding of behaviour and health are essentially required. Observation of behaviour can be done to evaluate behavioural patterns in terms of activity budgets and also help to detect any abnormalities and repetitiveness in behaviour. This often leads in developing better management practices related to behaviour and enclosure enrichment inside captivity. Regular monitoring of health condition of captive Manipur Brow-antlered deer is required for evaluating diseases and illness, body condition score, reproductive performance, survivorship in zoos. A healthy captive population ensures a successful pregnancy, increase the birth rate and normal behaviour. Thus, meticulous information of health and behaviour condition is definitely require in terms of captive management of Manipur Brow-antlered deer population.

Our goal is to review the up-to-date published studies on behaviour and health condition of Manipur Brow-antlered deer and the other related species to identify the gap areas and challenges in *ex situ* conservation. It also aims to initiate more investigation in this field which would ultimately lead to frame better management strategies for sustainable harvest of Manipur Brow-antlered deer in a captive environment.

2. Behaviour in captivity
Behavioural research in captivity serves as one of the major factors in conservation and management of animal species in an *ex situ* environment (Sutherland 1998) [67]. Basic behavioural studies provide relevant information whereas applied behavioural studies remove constraints in terms of breeding and management in zoos (Eisenberg and Kleiman

1977; Schaaf 1984) [20, 59]. These researches are the most common form of non-intrusive research which also help in estimating animal's health in captivity (Mallapur and Choudhury 2003; Sekar *et al.* 2008) [41, 61]. Behavioural studies on zoo animals always act as an important supplement to field and laboratory work. Nowadays, a number of researchers have inclined towards this kind of investigation (Burghardt 1975; Moran and Sorensen 1984; Wells 2005; Hosey 2005; Davey 2006; Hosey and Skyner 2007; Sekar *et al.* 2008) [13, 46, 72, 31, 17, 30, 61].

In order to carry out behavioural research, the behavioural methodology has been defined by Altmann (1974) [4]. It involves the construction of an ethogram and observation of behavioural patterns. An ethogram serves as an inventory of the behaviours of a species, in which behaviours are defined and organized into categories (Mallapur *et al.* 2005) [42]. The next step is the behavioural observations which can be done by various types of sampling techniques as suggested by Altmann (1974) [4]. Categorisation of behavioural data can be done into activity budgets, space usage, and social interactions for each individual (Pastorino *et al.* 2017) [54].

Some studies have been performed to describe various behavioural patterns of Manipur Brow-antlered deer in its natural habitat as well as in captivity. Mukherjee (1984) [48] has described the breeding behaviour of this species in its natural habitat, at Kiebul Lamjao National Park, Manipur. Detailed studies should be done regarding reproductive behaviour of brow-antlered deer in captive or semi-free ranging populations (Wemmer and Grodinsky 1988; Yuan *et al.* 1988; Zeng *et al.* 2001, Zeng *et al.* 2011) [73, 78, 79, 80]. Description of some general and reproductive behaviour in wild and captive habitat was reported in PHVA (1992) [55]. Sankhala and Desai (1970) [58] have made preliminary studies on the breeding behaviour at Delhi Zoo. Seasonal reproductive rhythms occur in Brow-antlered deer with a peak in breeding from March to May as well births from October to December (Aung *et al.* 2001, Song and Zeng 2003) [8, 66]. Wall and Hartley (2017) [71] related husbandary factors to the reproductive success and mortality in the Burmese brow-antlered deer in European zoos. Not many studies have been performed regarding behaviour identification in *ex situ* environment. There is still lacking a thorough knowledge of behaviour pattern and its importance in captivity.

A proper understanding of captive behaviour of Manipur Brow-antlered deer seems to be necessarily important in terms of identifying abnormalities and stereotypic pattern. The small population in their habitat gets decline or extinct because of many reasons, like abnormal/ stereotypic behaviour (Sutherland 1998) [67]. Deer population under captivity face major challenges to cope with a new environment, as there occurs a wide difference between the original/native area and the captive housing of the zoo population (DeWitt *et al.* 1998; Hendry *et al.* 2011; Carroll *et al.* 2014) [18, 29, 14] which ultimately result in behavioural changes. Those unnatural, exasperating environmental challenges include artificial lighting, noise exposure, restricted movement, reduced retreat space, human interference, maintenance in abnormal social groups, reduced feeding opportunities, and other restrictions of behavioural opportunity (Morgan and Tromborg 2007) [47]. These environmental variables thus lead to behavioural, physiological, psychological and adaptive changes in an individual or group in captivity which differentiates them from the wild population (Snyder *et al.* 1996) [65]. Also, raising animals in substandard environment often lead to the development of abnormal behaviours (Snyder *et al.* 1996) [65] and ultimately hampers captive breeding program.

Captive breeding programs should operate under carefully defined conditions of genetic/behavioural management. Abnormal behaviours and other behaviour related problems like aggression and infighting during breeding season often lead to failure in captive breeding (Snyder *et al.* 1996) [65]. According to PHVA (1992) [55] report on Manipur Brow-antlered deer, aggression between males (which affects females as well) results in high mortality rate, mainly during rut which ultimately reduces the fertile stock under captive environment. This also results in stress, trauma or other mental illness, which ultimately lead to food avoidance and poor health (Mcphee and Carlstead 2010) [44].

Reduction or elimination of abnormal or stereotypic behaviour and other behavioural problems in an enclosure can be done by enriching captive environment (Joshi 2015) [35]. Environmental enrichment is the process in which animals' captive environments are manipulated by providing appropriate space and various items that will help them to exhibit their species-appropriate behaviours and activity patterns and also enhance their well-being (Shepherdson 1998) [62]. According to Anderson *et al.* (2010) [5], environmental enrichment (enhancement) encourages natural behaviours inside the enclosure and help to enrich an animal's psychological and physiological state. A goal of enrichment is to reduce aberrant behaviours so that more naturalistic and captive habitat shall be given to animals in order to show normal behavioural pattern (Hutchins *et al.* 1984; Kreger *et al.* 1998; Mellen and MacPhee 2001) [33, 38, 45]. Thus, it is the major responsibility of all zoos to maintain natural behaviours under captivity with appropriate exhibit design, veterinary care, husbandry housing and enrichment programs (Mcphee and Carlstead 2010) [44]. Enclosure enrichment and correct diet in captivity often lead to the success of captive births in a zoo (Barat and Poyyamoli 2000) [10]. Environmental enrichment is emerging as a new scope in the field of animal husbandry by acting as a major and vital component of animal-care programs (Shepherdson 2003) [63]. These enrichment strategies should be applied to the different zoos in India holding Manipur Brow-antlered deer in order to tackle behavioural related problems inside the enclosure.

This overview revealed that the serious and precise behavioural studies of Manipur Brow-antlered deer should be required in terms of animal need, removal of constraints, and requirements in captivity. Also, in terms of space and environment, breeding requirements, health, food, social structure and, animal-man relationship (Hediger 1968; Brambell 1972) [28, 12]. This will further help in designing an environment defining their appropriate suitability in zoos. Thus, behavioural studies seem to be one of the major requirements in terms of management and conservation of a small wild population of Manipur Brow-antlered deer in *ex situ* habitat.

3. Health condition in captivity

Health is one of the major factors in *ex situ* conservation of captive population management in several zoological gardens. Undernourished food, poor sanitation, unhygienic condition, and irregular health check-up may develop zoonotic diseases, parasitic prevalence, and malnutrition. A proper health examination like the physical checkup, routine vaccination, and de-worming, parasitic screening and food assessment is necessarily required for proper growth and development of captive Manipur Brow-antlered deer (PVHA 1992) [55]. Wild animals get injury, infection or diseases in their natural habitat as well, but in zoos, these get a quick diagnosis and better treatment through Veterinary officials (Nemat *et al.* 2013) [52]. Thus, the overall health of wild animals in captivity can be achieved by regular monitoring of health and well-being, maintaining hygienic standards, providing space and shelter facilities, managing populations, training of staff and maintaining relevant records (Shukla *et al.* 2014) [64].

Proper diet and nutritious feed serve as important tools in maintaining good health condition of the animal in captivity (Rees 2011) [57]. Management and maintenance of a healthy and flourishing captive population can be done by providing an adequate nutritional diet. Nutrition is defined as the process by which an animal sustains its physiological activities such as growth, pregnancy, lactation and antler development through the food it eats (Vandeloecht *et al.* 2012) [69]. A nutritionally balanced diet comprising of an adequate amount of carbohydrates, proteins, lipids, vitamins, fiber, minerals and water serves as major and healthy requirement for a captive species. Required diet, on the basis of quality and quantity, differs from one individual to another according to their age, sex, physical activity and state of health (Rees 2011) [57]. Low energy intake as a result of insufficient food can slow down or even halt growth (including skeletal development) of an animal. It can also cause weight loss, reproductive failure, diseases and parasitic infestation (Dasmann 1981) [16].

Furthermore, the nutrient supplement which is given along with normal feed fulfills the condition of energy requirement needed for the growth, development and in the maintenance of a healthy captive population (Rees 2011) [57]. The addition of supplemental diet to the normal feed of captive wild deer population act as an important part of nutritional husbandry which helps to enhance their health, reproductive performance, and preventing these animals from malnutrition (Baker *et al.* 1998) [9]. The given feed should be supplemented with natural browse, trace minerals, and salt blocks to enrich their normal diet. In contrast to a nutritionally complete ration, supplemental diets act as an additional source of energy, protein, vitamins, and minerals (Raleigh and Foster 1972) [56]. Supplemental feeding offers a promising way to examine and enhance the overall health, performance and humane treatment of captive wild ruminants. Thus, it serves as a major portion of food enrichment, when the normal diet cannot be able to fulfill the criteria required (Raleigh and Foster 1972) [56].

Scientific observation of feeding patterns and food preferences also serves as an obligatory requirement in terms of health management of Manipur Brow-antlered deer. Wildlife managers should develop a proper understanding of food requirements of concerned deer (Dillard *et al.* 2006) [19]. The deer in wild feed their preferred food items but in captivity, these entirely depend upon the food or diet offered to them. It is literally essential to know about the specific feeding requirement of captive deer (Acharjyo 2004) [1]. Food preference defines the behaviour of selecting the food of choice for consumption (Gaalema *et al.* 2011) [23]. A proper knowledge of food preferences seems to be very necessary in order to examine carrying capacity and to improve habitat conditions (Bissell and Strong 1955; French *et al.* 1956) [11, 22]. In an *ex situ* environment, food should be given or presented in such a way that deer can spend its much time in feeding as in wild (Khanpara 2009) [36]. Monopolization of food by dominant Manipur Brow-antlered deer prevents feeding pattern as well as food preference of other deer in a herd, which can be controlled by establishing multiple feeding stations inside their enclosure. Proper care and management should be done in the case of pregnant and lactating females regarding their balanced diet under captivity (PHVA 1992) [55]. According to PHVA (1992) [55], diseases and mortality among wild as well as in captive Manipur Brow-antlered deer were found to be the potential reducing factor of the population. Diseases can cause animal death, increase in susceptibility to predation, lowered reproductive potential or combination of altogether (Scott 1988; Gulland 1995) [60, 25]. Poor health of animal or diseases in captivity not only nullifies the potential value of captive breeding programs but also lessens the success rate of translocation; which overall results in the negative effect on wildlife protection and conservation (Munson 1991; Viggers *et al*. 1993; Woodford and Rossiter 1993; Cunningham 1996) [50, 70, 77, 15]. There occur many aspects behind various types of diseases that an animal face in captive conditions. There involves a number of factors or causes behind any particular disease, that occur due to the unhygienic and incompatible environment inside an enclosure. Trauma is found to be a major cause of mortality in adult species (Hattel *et al.* 2004; Haigh *et al*. 2005; Ali *et al.* 2014) [27, 26, 2]. Over the past 30 years, the traumatic injury led to the mortality of Manipur Brow-antlered deer in captivity. These are generally related to inter-male aggression where females also get injured, followed by self-destructive behaviour; with less percentage than inter-male aggression (PHVA 1992) [55]. Other causes of mortality include infant mortality, infectious disease, and deaths from undetermined/unknown causes. In captive wildlife, the main causes of neonatal mortality are found to be unknown but sometimes, these seem to be related with natal-illness or because of inbreeding depression. Captive animals are also found susceptible to parasitic infection that is foreign to that particular species, an area of the animal's origin, an area of the animal's destination, or a combination of all three aspects (Frankham *et al.* 1986) [21]. These have more risk of parasitic disease due to an incompatible environment, changes in health condition and behavioural abnormalities than of wild animals; as they able to develop some natural resistance against parasites and related diseases (Atanaskova *et al.* 2011) [6]. The best method for controlling parasitic diseases in animals can be done by preventing direct or indirect contact between species, also by operating the components involved in the disease transmission (Allwin *et al.* 2016) [3]. Routine monitoring, regular deworming and hygienic measures should be done on regular basis to prevent parasitic

infections in captive species (Kvapil *et al.* 2017) [39]. Determination of the root cause of death under the captive breeding program should help in the establishment of a large and sustained population of Manipur Brow-antlered deer in several zoological gardens (PHVA 1992) [55].

Disease management of wildlife involves three basic forms i.e., disease prevention, disease control and disease eradication (Wobeser 2002) [76]. It seems to be a mandatory demand for conservation of rare and endangered species (Scott 1988; Hutchins *et al*. 1991; Lyles and Dobson 1993; Munson and Cook 1993; Gulland 1995) [60, 34, 40, 49, 25]. Transmission of disease in captivity needs to be prevented and controlled by vaccination or treatment and by reduction or lowering density of population under captivity (Killian *et al.* 2007) [37]. Prudent planning of disease management in *ex situ* environment requires regular monitoring of captive Manipur Brow-antlered deer herd. It is the systematic examination and collection of biomedical data from a species group for identification and finding disease prevalence. It should be done regularly in order to evaluate current health condition of a species and detect any disease outbreak or new diseases (Munson 1993) [51]. Each clinical case should be thoroughly investigated and examined with an effort to contrive a definitive diagnosis. Clinically ill animals should be given regular veterinary care by segregating or isolating them from the original herd with adequate treatment and medication in order to prevent disease transmission to other healthy individuals (PHVA 1992) [55]. Collaborations and coordination with veterinary and/or other medical institutes should be encouraged. Regular health screening including physical examination like general body condition scoring, as described by Audige *et al.* (1998) [7] and biological evaluation (blood, urine, and fecal tests) are essential to minimize animal health problems (PHVA 1992) [55].

In this way, regular surveillance of health condition will lead to assess disease concerns, malnutrition, determining feeding programs, selecting animals for breeding, thus help in evaluating and eradicating ill effects inside suboptimal environment of captive Manipur Brow-antlered deer in zoos.

4. Conclusion

Study on behaviour and health condition of captive Manipur Brow-antlered deer serves as an essential tool in framing prudent management planning for the zoological parks. The man-made environment inside enclosure often results in abnormal or self-destructive behaviour which ultimately leads to poor health and population declination. This can be tackled by environmental enrichment and by improvement of the habitat condition inside the enclosure (Newberry 1995) [53]. Thus, Behavioural studies lead to the identification of e environmental challenges, which help to set a better and more naturalistic environment inside the enclosure. Health is also one of the major factors in *ex situ* conservation of captive animals in zoos. Diseases, parasitic infestation, malnutrition, mental illness, trauma and low reproductive potential result in ill health of captive well-being. Regular surveillance of health should be required to provide information regarding general health status or any disease outbreak inside captivity (PHVA 1992) [55]. In addition to this, assessment of food and feeding pattern should be done for the development of a healthy captive population of Manipur Brow-antlered deer.

Adverse changes in behaviour and health condition can affect the physical, physiological and psychological states of deer population under *ex situ* environment; responsible for lessening reproductive potential, decreasing translocation and most important, increasing mortality rate. An extensive study is needed in terms of behaviour and health condition to develop effective management strategies so that a comparatively better environment can be established by reducing several negative factors under *ex situ* condition. The more scientific management planning should be incorporated into the captive breeding program in zoos for rapid multiplication, conservation, and reintroduction of endangered Manipur Brow-antlered deer.

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