Action Plan for the Reintroduction of Indian Mouse Deer

2018

CCMB

PREAMBLE

Reintroductions of native fauna are a rare practice globally and rarer still in India where it has only been attempted twice in recent times, for the red panda and the pygmy hog. After the resounding success of the mouse deer conservation-breeding program at Nehru Zoological Park, Hyderabad, the idea of reintroducing mouse deer in to the wild was mooted. Several rounds of meetings later, it was decided to go ahead with the plan. After due deliberation, when an area inside Amrabad Tiger Reserve, Telangana, was designated as the site for release and preparations were being made to draw the specifics, since there was no precedent available to follow, the need for a scientific protocol document that would serve as a guide was strongly felt. Therefore, this document serves as the first ever action plan for mouse deer reintroduction by soft-release. It provides an outline of the goals, objectives and the methodology that needs to be adopted to make the plan scientifically rigorous and accountable. This plan has been prepared in accordance with IUCN's Guidelines for Reintroductions and Other Conservation Translocations (version 1.0). It encourages all stakeholders of Indian wildlife conservation to use this document to plan reintroductions. It urges other forest departments to come forward and consider repopulating their depleted forests with the enigmatic Indian spotted chevrotain.

ACKNOWLEDGEMENTS

This document is the result of a cooperative effort by several people with a common desire to rewild degraded forests. They have directly or indirectly contributed to its compilation and brought the program to realization. The leadership of Central Zoo Authority in recognizing the need for conserving the mouse deer cannot be understated. The role of Nehru Zoological Park, Hyderabad, as the coordinating zoo for conservation-breeding program for pygmy hogs has been immense. Its resolve in getting the program started cannot be commended enough. The baseline data generated through hours of rigorous observations has proven crucial. Amrabad Tiger Reserve's enthusiasm and infectious zeal when it comes to the reintroduction of this enigmatic but lesser-known species in its premises is much appreciated. Telangana Forest Department's dedication to the long-term vision on conservation of the state's natural heritage in spite of the challenges it faces is refreshing. The technical expertise provided by the Laboratory for the Conservation of Endangered Species, CSIR-Centre for Cellular and Molecular Biology, in matters concerning monitoring design and documentation has been invaluable. A debt of gratitude is owed to Dr. N. V. K. Ashraf for reviewing the initial draft of the action plan and providing valuable insights and constructive comments. Finally, perhaps the biggest cheer must go to those foot-soldiers of conservation: the animal handlers who painstakingly raised the mouse deer in captivity and the forest personnel who would be helping them find a new home in the wilderness.

Contributors-

The following institutes and people have contributed to the preparation of the plan:

CENTRAL ZOO AUTHORITY

Brij Kishor Gupta

D. N. Singh, IFS

Devender Kumar

CSIR- CENTRE FOR CELLULAR AND MOLECULAR BIOLOGY

Ajay Gaur

B. Sambasiva Rao

Drashti Parmar

G. Umapathy

Karthikeyan V.

M. S. Ram

Noopur Modi

P. Anuradha Reddy

Rama Sarvani

Sadanand Sontakke

Sandeep Goel

Snehalata Vadigi

Srinivas Ara

Wajeeda Tabasum

Vinod Kumar

TELANGANA FOREST DEPT.

A. Shankaran

Chandrasekhar Reddy

Munindra, IFS

P. K. Jha, IFS

Vinay Kumar, IFS

NEHRU ZOOLOGICAL PARK

B. Laxmi Narayana

G. Venkatesh

M. A. Gaffar

M. A. Hakeem

M. Rajaiah

Mahesh

Mallikarjun Rao, IFS

Mushkam Sandeep Goud

Naveen

Navin Kumar

Raheem

Shivani Dogra, IFS

Srinivas

Swapna Parvathi

Syed Asadulla

AMRABAD TIGER RESERVE

Balu

Bapu Reddy

Guruvaiah

Joji

Linga

Malinath

Ravikumar

Sridevi Saraswati

Suresh

Vinod Kumar, IFS

Citation-

Reference:

CSIR-Centre for Cellular and Molecular Biology & Nehru Zoological Park. (2018). *Action Plan for the Reintroduction of Indian Mouse Deer* (1st ed.). Hyderabad, India: Author.

In-text citation:

(CSIR-CCMB & NZP, 2018)

Contents

Executive summary 1

1. *Introduction*

1.1. Introduction 3

1.2. Extinction causes and threats 5

1.3. Alternatives to reintroduction 6

1.4. Conservation-breeding program 7

2. *Goals, objectives and methods*

2.1. Establishment phase 11

2.1.1. Identification of suitable habitats for reintroduction 12

2.1.2. Establishment of soft-release facilities 13

2.1.3. Acclimatization of captive-bred individuals for release 16

2.1.4. Monitoring animals in the release facility 17

2.1.5. Post-release monitoring of reintroduced population 22

2.2. Growth phase 26

2.3. Regulation phase 27

3. *Feasibility and design*

3.1. Background biological and ecological knowledge 28

3.2. Models and precedents for same/similar species 29

3.3. Habitat 29

3.4. Climate requirements 30

3.5. Founders and genetic considerations 30

3.6. Disease and parasite considerations 31

3.7. Legal requirements 32

3.8. Financial and budget considerations 32

4. Risk assessment

4.1. Assessing the risk landscape 34

4.2. Risk to the source population 34

4.3. Ecological consequences 34

4.4. Disease risk 35

4.5. Invasion risk 35

4.6. Gene escape and interspecific hybridization 35

4.7. Socio-economic risks 36

4.8. Financial risks 36

5. Release and implementation

5.1. Selecting captive-bred individuals for release 37

5.2. Capture of individuals 37

5.3. Transportation of individuals 38

5.4. Acclimatization of individuals 38

5.5. Release of individuals 39

5.6. Post-release monitoring 40

5.7. Evaluation of reintroduction success 40

6. Outcome assessment and continuing management

6.1. Pre-release survey and monitoring 42

6.2. Post-release monitoring 43

6.3. Continuing management 43

6.4. Exit strategy 44

7. Dissemination of information 46

References *48*

Executive Summary

This document provides an outline of the process of reintroduction of the Indian spotted chevrotain. It is divided into seven sections.

The first section introduces the Indian spotted chevrotain, its taxonomic position among ungulates, its behaviour and ecology, and its distribution. Furthermore, it lists the threats to its survival and justifies the need for reintroduction as a conservation strategy.

The second section lists the goals of the reintroduction program, its objectives, and the methods that must be employed to achieve those objectives. Briefly, the goal of the reintroduction program is to re-establish persistent populations of mouse deer in areas from which it has been extirpated. The program is broadly divided into three phases: establishment phase, growth phase and regulation phase. Establishment phase involves the initial preparations required for release, and the releases until the reintroduced population starts growing naturally. It consists of identification of suitable release sites, establishment of a well-designed, soft-release facility, acclimatization of mouse deer in the soft-release facility, and monitoring them pre- and post-release. The soft-release facility should be divided into three compartments, each serving a different conditioning stage. Each stage should facilitate, incrementally, the weaning of the mouse deer from its dependence on captive conditions and prepare it for life in wild. This section also details the various methods that should be used to monitor the mouse deer pre- and post-release to assess progress of individuals and to evaluate the reintroduction success, and the changes required in the monitoring design during the growth and regulation phases of the program.

The third and fourth sections deal with the feasibility of the program, e.g., suitability of habitat, genetic fitness of source population and financial considerations, and the expected risks of reintroduction including disease risk or potential invasions. It also summarises the findings about mouse deer's biology and behaviour gleaned during its conservation-breeding program at Nehru Zoological Park.

The fifth section details the requirements for selection of individuals from the conservation-breeding facility in the zoo, their capture and transportation to the soft-release facility. It briefly discusses the implementation of monitoring and release, and the evaluation of the reintroduction success based on the data accrued.

The sixth section defines the assessment of outcome by monitoring, how it should contribute to the decision-making process and long-term management. It also defines the exit strategy that must come into force if any serious problems are faced by the reintroduction program or if it fails to achieve its goals within a stipulated amount of time. The exit protocol lists the steps that must be taken to prevent potential or further loss of mouse deer individuals.

The seventh and final section discusses the need for dissemination of information both with scientific and non-scientific communities. It lists various ways in which the public can be engaged to create awareness about the program and its significance.

Overall, this document serves as a standard operating procedure for future reintroduction programs involving the mouse deer. Reintroductions are risky and are prone to failure due to many factors. A scientifically robust procedure would not only help in decision-making but also in the identification of factors that have the greatest impact on the survival of the reintroduced population.

1. Introduction

1.1 Introduction

The Indian spotted chevrotain or mouse deer (*Moschiola indica*) belongs to the ruminant family Tragulidae in order Cetartiodactyla. Tragulids are a monophyletic group basal to all other member of the clade Ruminantia, a group of related even-toed ungulates such as pronghorns, giraffes, deer, musk deer, antelopes and cattle (Hassanin et al., 2012; Sarvani et al., 2018).

Generally, all tragulids are diminutive relative to the average ruminant, have short limbs and an arched back with toughened skin to enable them to scurry through the dense undergrowth of forests which they inhabit, have a spotted coat that provides excellent camouflage against potential predators and sport large, sabre-like upper canines that are used in territorial combats between males. They are nocturnal or crepuscular as indicated by their large eyes and prefer to rest during the day. They have a litter size of one and the single infant is left behind in a densely vegetated refuge, while the mother forages. Being solitary, interactions between individuals are limited to territorial confrontations and mating.

Tragulids occupy important ecological roles as seed dispersers and serve as prey to several small and large carnivores. Compared to other ruminants of the humid tropics, they have a high energy requirement per unit body mass and low daily water intake. However, they maintain a higher water content in their bodies, thanks to a diet with high water content and relatively dry faecal pellets. Their diet consists of easily digestible forage providing extremely high protein e.g., fallen fruits, seeds, flowers, leaves, shoots, mushrooms etc. Their bodies, consequently, contain high percent of muscles and very little fat. Tragulid stomach morphology resembles that of pecoran (sister clade of Tragulidae in Ruminantia) concentrate-selectors but differ from them in having a much-reduced omasum and a small rumen. Furthermore, tragulids are also set apart from

pecorans by their diffuse placenta similar to camelids and suids, with whom they also share certain breeding behaviours.

The earliest fossil evidence of Tragulids is from the Late Eocene (Sánchez, Quiralte, Morales, & Pickford, 2010) epoch (Kamalakannan & Manna, 2013) implying a divergence from the sister clade Pecora earlier than that. Fossil records were sparse until the Miocene when suitable environmental conditions and conducive habitat (Rössner, 2004) allowed several genera to flourish in Africa, Asia and Europe (Mein & Ginsburg, 1997; Pickford, 2001, 2002; Sánchez et al., 2010; Sánchez, Quiralte, Ríos, Morales, & Pickford, 2015). However, the current tragulid diversity is much reduced and is limited to just three genera comprising of nine species occurring in the tropical and sub-tropical forests of Africa, South Asia and Southeast Asia: *Moschiola* (*M. indica* in India and probably Nepal, *M. meminna and M. kathygre* in Sri Lanka), *Tragulus* (*T. javanicus, T. napu, T. kanchil, T.nigricans, T. williamsoni* and *T. versicolor* in Southeast Asia, particularly in the islands of Indonesia) and the monospecific genus *Hyemoschus* (*H. aquaticus* in equatorial Africa). Their present disjunct distribution and their primitive physical appearance have prompted some people to label them as them living fossils. Recent phylogenetic analysis of the complete mitochondrial genome has suggested that genus *Moschiola* is basal to remaining two tragulid genera (Sarvani et al., 2018).

The Indian spotted chevrotain (*Moschiola indica*) was split from *M. meminna* on the basis of differences in skin and skull morphology (Groves & Meijaard, 2005). It is small (1 – 3 kg) and cryptic (Fig. 1). Only a few sporadic studies have been conducted on its distribution, ecology and behaviour (Basak et al., 2017; Eisenberg & Lockhart, 1972; Kumbhar, Prabhu, & Yogesh, 2013; Prasad & Sukumar, 2010; Ramesh, Kalle, Sankar, & Qureshi, 2013; Sridhara, Edgaonkar, & Kumar, 2013), creating a large gap in knowledge about the species. Although it is classified by IUCN Red List as “Least Concern”, the

current population has been on the decline. The status of protection accorded to the species highlights the threats it faces in its habitat.

Figure 1: Indian spotted chevrotain or mouse deer (*Moschiola indica*).
Photo credit: Mushkam Sandeep Goud (MSG).

1.2 Extinction causes and threats

Indian spotted chevrotain was widely distributed across the Indian subcontinent but has been extirpated or reduced to numbers below detection levels in several disturbed forest areas. In Nepal, where its presence was recorded from the forested lowlands till 1960s, rapid habitat destruction has led to its apparent extinction (Baral et al. 2009). Understorey structure and the presence of potential refuges have a positive effect on their habitat use (Sridhara et al., 2013) implying their reliance on undisturbed forests. Moreover, Indian spotted chevrotain is among the most hunted forest fauna (Kumara & Singh 2004) and it's believed that hunting pressures have contributed to a noticeable decline in its densities (Madhusudan & Karanth, 2000). Despite its widespread

distribution, its inherently low population density makes it highly vulnerable to the aforementioned threats (Karanth, Nichols, Karanth, Hines, & Christensen, 2010). However, recent measures have reduced the threat of hunting in many areas making them conducive for re-establishment of the species.

Reintroductions of locally extinct chevrotain are not only recommended but are a necessary condition for the long-term survival of the species. Moreover, reintroductions with the aim of supplementing small populations may help in preventing further population decline and local extinctions. Reintroductions may also have long-term benefits for the survival of the species by re-establishing geneflow between isolated populations and by increasing the genetic diversity of populations. The Indian spotted chevrotain is an important component of the forest ecosystem. It serves as disperser of several native fruit trees by consuming the fallen fruit (Prasad, Pittet, & Sukumar, 2010) and is an important prey species for predators like dhole (Dar & Khan, 2016), leopard (Ramesh et al. 2009) and eagle-owl (Nandini 2005). There are no species that could replace the chevrotain's ecological role in these forests making their reintroduction paramount for the health of the forest ecosystem.

1.3 Alternatives to reintroduction

Alternatives to reintroduction would include reforestation of large swathes of agricultural landscape to encourage natural migration of Indian spotted chevrotain from forests where it's present. Such alternatives will take decades to show results, which could further hamper conservation efforts. Furthermore, this option is both economically and politically untenable.

1.4 Conservation-breeding program

The Nehru Zoological Park in Hyderabad, Telangana, had initiated a conservation-breeding program in 2010 as the coordinating zoo along with Nandankanan Zoological Park, Bhubaneshwar and Sri Chamarajendra Zoological Garden, Mysore as the participating zoos. The program has been a resounding success with a population of 231 individuals as of March 2018. Initially, 6 founders (2 males and 4 females) were used of which 3 (1 male and 2 females) were wild-caught from the forests near Tirupati, Telangana (Parvathi, Rao, Kumar, & Umapathy, 2014). However, the captive population has frequently been supplemented by additional founders of wild-origin. Dedicated mouse deer enclosures were constructed in the non-visitor area (Fig. 2). Trees (palm, bamboo etc.) and grasses to simulate natural habitat, and hollow tree trunks and artificial shelters made of grass were provided as enrichment to encourage breeding (Fig. 3). The regular diet consisted of apple, banana, carrot, beans, sweet potato, mixed grains, lucerne, *Acalypha*, *Ficus* and mineral mixture (Fig. 4). Apart from these, seasonal fruits like berries and gooseberries were provided whenever available.

Figure 2: An enriched mouse deer enclosure under the conservation-breeding program initiated by Nehru Zoological Park, Hyderabad. Photo credit: MSG.

Figure 3: A pair of mouse deer using an artificial shelter. Photo credit: MSG.

Figure 4: Typical diet containing processed fruits and vegetables provided for the captive-bred mouse deer. Photo credit: MSG.

Since the inception of the conservation-breeding program at Nehru Zoological Park, the breeding population's behaviour and natural history parameters have been continuously monitored (Parvathi et al., 2014). It has been noted that the mouse deer breeds throughout the year, but most births occurred in the post-monsoon season (September-February). Females display first oestrous at as low as 145 days old. Gestation period is 154 days on average and the inter-birth interval is only slightly higher, meaning the females are capable of conceiving within a few hours of giving birth. In concordance, mating was observed on the same day females gave birth. The litter size is usually one (Fig. 5), but a case where a female gave birth to twins was observed. The captive population is also being used to estimate birth and growth rate of the species in captive conditions. This data should inform reintroduction decisions like the number of individuals to be released and the optimum release rate. If there's a need to reduce the captive population, the harvest can continue until the captive population reaches pre-determined critical size. In a stable captive population, the harvest rate from the

conservation-breeding facility should not exceed the growth rate as the program is envisaged with long-term repopulation goals in mind.

Figure 5: A mouse deer mother with her fawn. Photo credit: MSG.

Being prolific breeders given suitable conditions and lack of threats, the conservation-breeding program has faced few issues. However, low genetic diversity in the founder population (a consequence of few or related founders) and unscientific population management can lead to genetic inbreeding and loss of genetic diversity. Therefore, the captive animals should be genotyped to ascertain their relatedness in order to inform breeding decisions. The genotyping would also help identifying individuals in the post-release monitoring phase of the reintroduction program. Furthermore, steps shall be taken to supplement the gene pool of the captive-populations by incorporating rescued individuals or those obtained from other captive populations.

2. Goals, Objectives and Methods

The goal of the program is the re-establishment of persistent populations of Indian spotted chevrotain (henceforth referred to as mouse deer) in the forests of Telangana where they were historically present but wherefrom they have been extirpated and to increase the probability of persistence in forests where their numbers are in decline. The program should operate in three phases: the establishment phase, the growth phase and the regulation phase, each with its own set of objectives and actions. Continuous post-release monitoring is essential for the identification of phase transitions.

2.1 Establishment phase

This phase starts from the first release till the time when post-release effects like higher predation risk are no longer operating on the introduced population. The aim of this phase should be to plan the release in a manner that reduces post-release effects. This would encompass choice of individuals and release area, acclimatization and monitoring of the individuals.

The specific short-term objectives of the program under this phase include:

- Identification of suitable habitats for reintroduction
- Establishment of soft-release facilities
- Acclimatization of individuals for release
- Monitoring animals in the release facility
- Post-release monitoring of reintroduced population

2.1.1 Identification of suitable habitats for reintroduction

Mouse deer historically inhabited evergreen and deciduous forests across the Indian subcontinent. However, destruction of habitat and hunting for meat has considerably reduced their population from several places and has driven them to extinction in some. These threats have been curtailed in many areas by better forest management and stringer law enforcement, making them suitable for reintroduction of the species.

For the reintroduction program, areas shall be identified for its implementation and, locally, sites for release should be identified. Generally, the areas must meet two main requirements-

- Presence of a large, continuous forested area
- Lack of threats in the form of hunting and habitat degradation

Telangana Forest Department records on number of hunting and logging cases in the recent past should be used as indicators of area suitability. Frequent review of these records is recommended for identifying new threats as they can be detrimental to the program's goal.

Once the areas are identified, specific sites for the soft-release should be identified based on the presence of dense vegetation thickets (tree and undergrowth density) that can serve as hideouts and presence of high number of fruiting trees. Understorey complexity and potential refuges have proven to be important for survival of mouse deer (Sridhara et al., 2013). Local predator densities should also be estimated to reduce predation risk that might hamper the initial establishment of the population by significantly lowering recruitment.

2.1.2 Establishment of soft-release facilities

Soft-release facilities should be established at the identified release sites. They should be spacious compounds open to the canopy and contain native vegetation. The enclosure should be divided into three compartments housing individuals at various stages of conditioning (Fig. 6), which would ensure a higher release rate while preventing territorial conflicts. The individuals in the conservation-breeding facility are kept in smaller contained areas, and although enrichment is provided, being solitary animals, scuffles frequently occur between individuals presumable due to lack of territory. Therefore, one of the priorities of the release facility should be increase the space availability. Each compartment should be more spacious than the previous (except for the final compartment, for reasons explained below). The individuals in the conservation-breeding facility are kept in enclosures of area 120 m^2 with area available per individual at 40-60 m^2. The first stage or 'stabilization stage' should introduce the mouse deer to a larger area with 150 m^2 available per individual (for a release batch of 10 individuals). The second stage or 'acclimatization stage' should be much larger with an area of approximately 3000 m^2 and a release of ten individuals would increase the area available per individual to 300 m^2, almost eight-fold increase from the zoo enclosures. Each compartment should also be designed to fulfil the needs of the conditioning it would be used for (see section 2.1.3). For example, the acclimatisation stage where naturalisation of the captive-bred population is planned should be the largest in area and most representative of the release habitat, and the release enclosure should be small and hostile enough to encourage the mouse deer to move out.

The compartments should be connected to each other via gates that can be opened (Fig. 6). Transfer of animals from one conditioning stage to the next should be carried out by manually chasing the animals into the next empty compartment through

these gates with visual verification to ensure that no individual remains back. In addition, camera traps should be set up at every exit to record the individuals. To ease the process of moving individuals housed from one compartment to the next, it is recommended that they form a tapered shape leading the gate at the end. In the first and second compartments, water should be provided close to the gates to encourage mouse presence near the gate and to facilitate their easy transfer. The last compartment should have a door open to the wild habitat. It should have a relatively hostile environment (sub-optimal availability of food, water and shelter) that is expected to encourage the mouse deer to voluntarily leave the release facility in search of better living conditions in the surrounding forest. Necessary steps should be taken in designing both the enclosures and the exit door for preventing the entry of predators into the enclosure. It is recommended that the exit door should consist of a small tunnel with a long, drooping cloth on the outside to enable only single-way entry, preventing entry from the outside. Suitable alternatives to this design could also be explored.

The entire structure itself should ensure protection the mouse deer from small and large mammalian predators from outside. A 10-foot tall fence reinforced with live wire is recommended as the primary barrier to the entry of predators. The enclosure must contain native flora, particularly shrubs and fruit-bearing trees that can potentially fulfil the nutritional requirement of the mouse deer. Artificial huts should be provided for shelter for the mouse deer in the first compartment and a few evenly-spaced thickets should be provided within the enclosures to serve as refuges in the second compartment.

The fate of the soft-release facility at the end of the program should be deliberated upon. Potential uses could include using them as on-site rescue and rehabilitation centres or adapting them for reintroduction of other species.

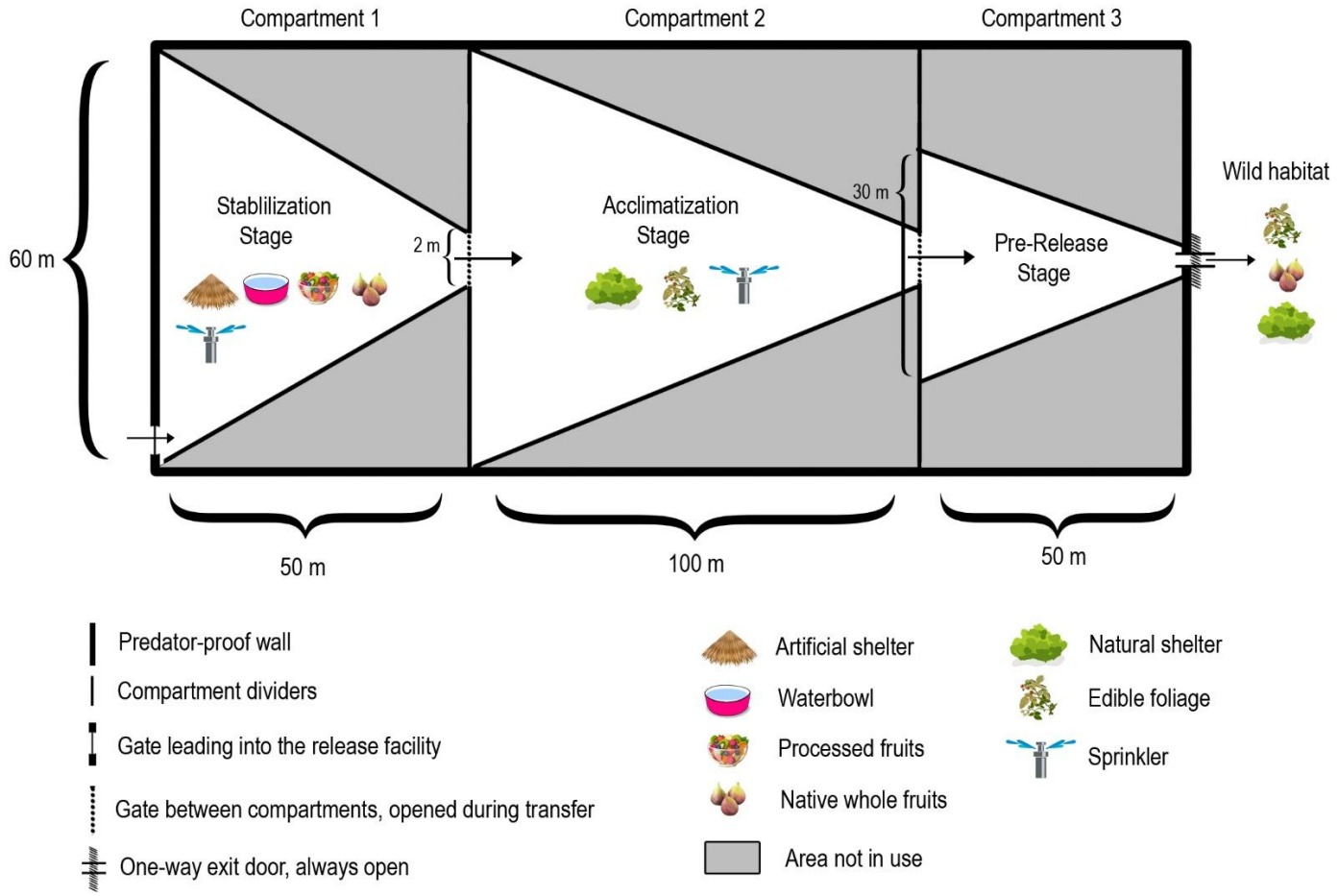

Figure 6: Recommended design for the soft-release facility showing the three compartments and the qualities of each conditioning stage.

2.1.3 Acclimatization of captive-bred individuals for release

The mouse deer at the conservation-breeding facility at Nehru Zoological Park are kept in a completely isolated environment and provided with a diet of processed fruits like apple, banana and carrot etc., that is served to them at specific times of the day. Although there is enough enrichment for their well-being, it's not sufficient to condition them for life in the wild where they must forage for food, avoid predators and seek their own shelter. Hence, acclimatization is of paramount importance for the survival of released individuals. The main purpose of the soft-release facility is to house the captive-bred individuals in the facility until they are deemed to be self-reliant and fit for release. The progress of the conditioning process should be constantly recorded using certain indicators (see section 2.1.4).

Conditioning should be done in three stages with each stage incrementally facilitating the transition of the animals from the zoo conditions to the wild.

i. The first stage (stabilization stage) should at least be 14 days long. It should introduce the mouse deer to an open enclosure and they should be fed a mixed diet of processed fruits/vegetables as in the conservation-breeding facility and whole fruits/vegetables strewn across the enclosure. The proportion of processed fruits should be reduced gradually through the duration of the stage, ending with no processed fruits being provided, i.e., 100% on first two days, followed by 75%, 50%, 25%, and 12.5% for two days each on subsequent days. No processed fruits should be provided on the last four days. The whole fruits that were placed to encourage foraging should include fruits native to the surrounding forests. At the end of 14 days, if all the indicators have been observed, the animals should be driven to the next compartment for stage 2 of the conditioning process.

ii. The second stage (acclimatization stage) should also last at least 14 days. In this stage, the mouse deer should not receive any food supplements in the form of processed fruits/vegetables and the entire diet should consist of only natural forage available in the form of fallen fruits, tubers and leaves etc. This stage should be carried out in the second compartment which should be the largest in area and the most representative of the release habitat. At the end of the 14-day period, if the necessary indicators have been observed, the animals should be manually chased into the next compartment for stage 3 of the conditioning.

iii. The final stage (pre-release stage) is not time-bound as the mouse deer are expected to voluntarily move out of the enclosures. It should present a sub-optimal environment with no dedicated water source, food resources or shelter. The compartment should have a door that's under camera trap surveillance to recording exiting mouse deer.

2.1.4 Monitoring animals in the release facility

The animals in the release facility should be monitored to assess their release-readiness in the first two stages. Both behavioural and physiological indicators for conditioning should be recorded. Behavioural indicators for mouse deer in the stabilization stage may include consumption of whole fruit, foraging for fallen fruits, responding to alarm calls etc., while those in the acclimatization stage may include consumption of non-fruit food, hiding in bushes, using the entire compartment area etc. The individuals should be under constant surveillance from CCTV cameras or camera traps placed at strategic locations to monitor their behavioural indicators. Expected behaviours for each conditioning stage should be ticked off for every

resident in that compartment (Table 1). Any mating behaviour should also be recorded to estimate post-release growth rate. All individuals in each stage must show at least two indicators and more than 50% must show all before the individuals are released to the next stage.

The physical fitness of the individuals should be objectively assessed by assigning body condition scores based on visual estimates (Table 2; adapted from Robinson, 1960). The scores in descending order of fitness, ranging from 10 (mouse deer in prime condition) to 0 (dead individual), should be used to asses the fitness at each stage of the reintroduction process, beginning from selection in conservation-breeding facility to assessment during each conditioning stage. Only individuals that score 7 or more should be selected for the next stage.

Physiological indicators such as stress and disease should also be monitored continuously. Physiological stress is known to affect the animals' vulnerability to relocations not only due to its effect on their health but also due to its influence on their cognitive abilities which play a major role in adaptation to new environments (Teixeira et al. 2007). Hence, examining physiological stress during and after transportation to the soft-release facility is of paramount importance. Faecal samples should be sent for non-invasive hormone analysis using cortisol metabolites to determine if the animals are under stress. The baseline values must be determined in the chosen release population before they were transferred to the release facility. Faecal samples should also be used for disease diagnosis if an illness is suspected.

If the physiological indicators, i.e., body condition score of 7 or more, and lack stress and parasites, are not achieved, or if there's deterioration of these indicators during the conditioning, the individuals should be nursed back to a normal state

before reincorporating them into the acclimatization regime. If an individual shows physical deterioration on the second attempt too, it should be taken back to the conservation-breeding facility. If the behavioural indicators are not met, the conditioning period should be extended until they are.

Identification of individuals is important for determining the level of acclimatization and its correlation to post-release survival. Mouse deer physically restrained for regular health check-up have been inserted with transponders with unique IDs that may help in identification of carcasses. For identification of live animals, since variations in coat patterns cannot be reliably used for this purpose, individuals should be marked. However, the marking technique should not interfere with the animal's ability to survive after release (Ricker 1956). This rules out the use of radio collars as they would be cumbersome. There's also a chance that the collars would fall off the animal because body tapers towards the head. Harnesses for housing the transmitter run the risk of snagging on vegetation because of the behaviour of the animal. As an alternative, freeze-branding (depigmentation of fur using an iron or copper brand cooled with dry ice) as a permanent marking technique has been tested in small mammals with good results (Hadow 1972). It is also safer than other marking methods like tagging (Murray & Fuller 2000). In the mouse deer, as with larger ruminants, the upper thigh region could be used to brand individuals as they are relatively less sensitive and easier to spot. The usability of freeze-branding should first be tested in animals kept in the conservation-breeding facility before being applied to the animals chosen for release.

In the long-term, the objectives under the plan should also encompass the development of suitable research capacity for ensuring scientific monitoring and setting up of relevant facilities.

Table 1: Example behavioural indicators chart showing progress of mouse deer individuals. All individuals must show at least two indicators and more than 50% must show all indicators before the individuals are released to the next stage.

	Stabilization stage			Acclimatisation stage		
	Consuming whole fruit	Foraging for fruit	Exploratory/social behaviour	Foraging for natural food	Using natural hiding areas	Movement in the entire area
Male 1	✓	✓	✓	✓		
Male 2	✓		✓			
Female 1	✓	✓	✓			
Female 2	✓	✓	✓			
Female 3	✓					

Consuming whole fruit: Mouse deer should be seen/recorded nibbling the whole fruits or putting them in their mouths.

Foraging for fruit: Whole fruits must be placed on the ground, away from the feeding bowl, near the camera traps. Mouse deer must be recorded approaching the fruits, sniffing them and eating them.

Exploratory/social behaviour: Observation of mouse deer individuals moving around the enclosure exploring it, chasing each other or mating.

Foraging for natural food: Mouse deer must be recorded approaching any part of the plant, manipulating it with its mouth and eating it.

Using natural hiding areas: Mouse deer must be seen using the natural shrubbery in the compartment as refuges when disturbed.

Movement in the entire area: Signs of mouse deer presence in the different sections of the compartment must be recorded by camera traps or by presence of faecal pellets.

Table 2: Body condition scores based on visual estimates of physical fitness in mouse deer.

Body condition score*	Visual observation of physical features
10	Prime, fat appearance; Smooth lines, heavy legs and round, full shoulders.
9	Just beneath optimum appearance; Shoulders, legs and back not fat but still smooth and full.
8	Good appearance; slight definition about the shoulders or slenderness of legs.
7	Average condition; neither fat nor thin, slight demarcation between neck and shoulder,
6	At least one of the following is observed: a) Clear definition of neck from shoulders, b) upper arm distinct from chest or c) noticeable thinness of legs.
5	At least two of the conditions listed in score 6 are noted.
4	Overall thin appearance; All three of the conditions listed in score 6 are observed.
3	Hide fits loosely about the neck and shoulders; Walking and running occur without weakness.
2	Malnutrition is apparent; Thin legs, evident outline of scapula, humped or sagged back; Still able to walk and run, but lethargic.
1	Stage of malnutrition from which recovery is impossible; Overall weak appearance; Walking is uncertain and on spread toes, running is not possible.
0	Dead animal.

* Individuals that score 7 or more should be transferred to the subsequent conditioning stage

2.1.5 Post-release monitoring of reintroduced population

Perhaps the most vital and hardest part of any reintroduction program is the post-release monitoring of the individuals. Post-release monitoring of elusive species like mouse deer with low detection probabilities warrant a need for multiple simultaneous approaches. Records of environmental and habitat parameters must be recorded for each successful sighting or identification of mouse deer outside the release facility. The main monitoring methods include:

- *Manual survey*: Regular surveys should be conducted on foot by forest personnel in an area up to 3 km^2 from the release facility for signs of mouse deer presence viz. visual sightings, hoof prints, faecal pellets, hair, carcass and bones. These signs and their locations should be recorded. In case of visual sighting, attempt should be made to identify the individual and take photos. Samples of faeces, hair and carcass should be collected and preserved for molecular analysis (see “microscopic analysis” and “molecular analysis” in this section for more information on sample preservation). Signs of mouse deer presence during surveys carried out in the rest of the forest should be reported to the release facility.

- *Camera trap*: Camera traps should be placed at regular intervals along at least 10 concentric circles such that the area encompassed by the central circle (radius, R_1 = 309 m) and each subsequent concentric ring equals 0.3 km^2, giving a total coverage of 3 km^2 (R_{10} = 977 m) (Fig. 7). Each circle should be divided into six sectors and camera traps should be set up at points where the spokes intersect the circles (Fig. 7). Each circle can be

thought of a line Such an arrangement would enable higher encounter rates near the release site, where mouse deer are expected to be more numerous, that would help in better monitoring of survival of individuals. It would Motion-sensitive infrared detectors should have their sensitivity set to high. The centre of the circles should be the exit door of the final compartment. The camera traps should be placed at a height of 30-35 cm from the ground, low enough to capture the diminutive mouse deer, and 3-5 m away from narrow trails that could potentially be used by them (Ramesh et al. 2012) to reliably detect mouse deer and identify individuals. On any given day, half the traps should be randomly chosen for baiting with fruits for increasing detection probability. The bait should consist of 2-3 natively occurring fruits that the mouse deer were observed feeding on in the release facility. The bait should be placed at about 3 m from the camera trap and the distance between the trap and the bait must be cleared of stray branches for best capture of the individuals for identification. The traps must be operated in the video mode with 10 seconds of recording. The trap stations must be operated 24 hours a day and visited once every week to record the data. If mouse deer are trapped, the photos must be scrutinised for identification of individuals from their markings.

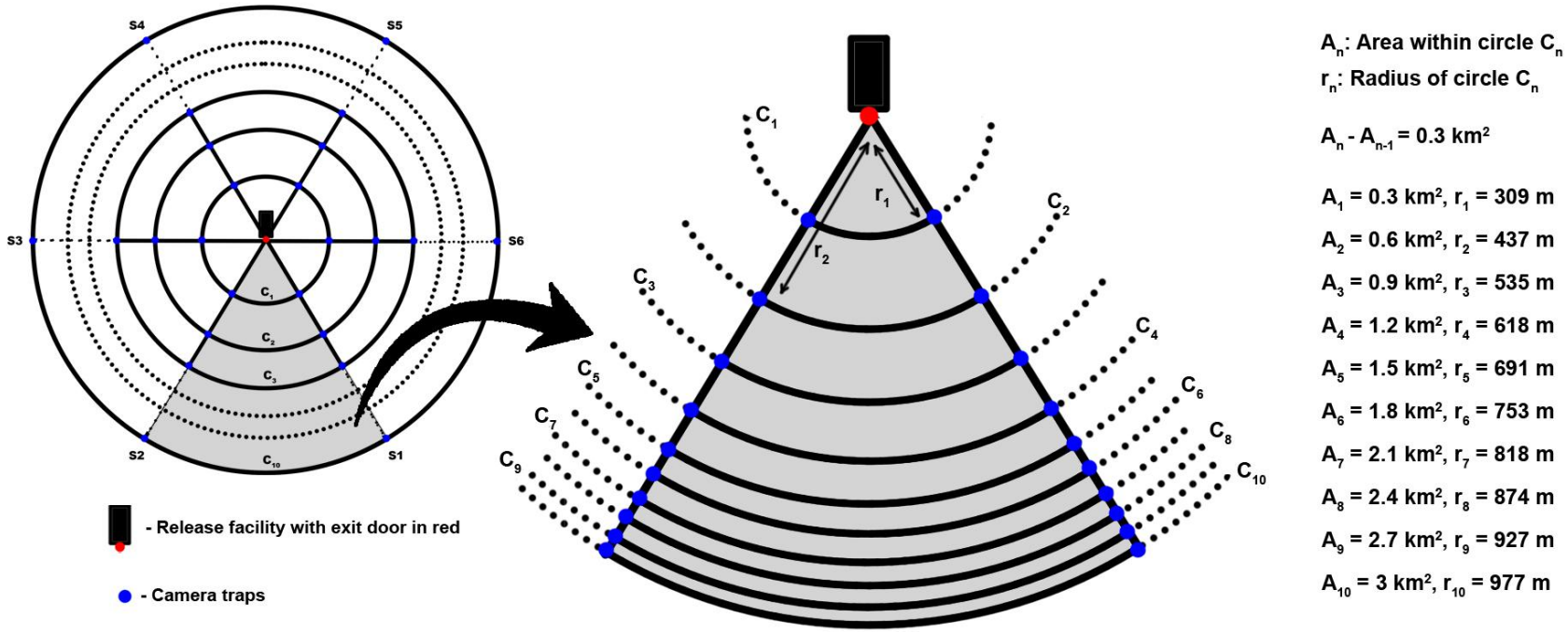

Figure 7: Illustration showing the camera trapping design. Left: Concentric circles C_1-C_{10} with spokes S1-S6 and the soft-release facility in the centre; Centre: A sector of the outermost circle; Right: Distances from the exit door to each circle r_1-r_{10}.

- *Microscopic analysis*: Microscopic analysis of hair is a quick and effective way of identifying species. Hair from decomposed carcass or scat samples of potential predators like dhole and leopard should be collected and dry-preserved in vials before sending them to lab for microscopic analysis. The dorsal guard hairs of mouse deer could help in its identification. The microscopic surface and medullary structure of the hair (Fig. 8) helps distinguish mouse deer from other ungulates (Kamalakannan & Manna, 2013). Predator scat must be analysed for mouse deer prior to release of the animals too. Such data would help in better understanding of predation risks in the area chosen for reintroduction. The procedure for preparing the hair samples for identification is detailed in Kamalakannan & Manna, 2013.

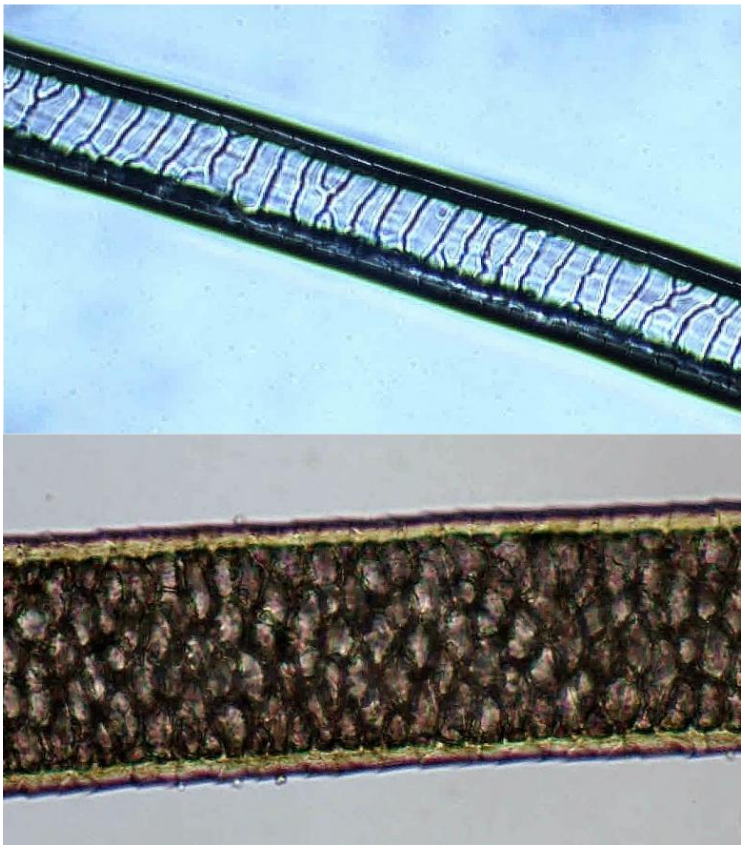

Figure 8: Microscopic surface (top) and medullary (bottom) structures of mouse deer dorsal guard hair. Photo courtesy: Kamalakannan & Manna, 2013.

- *Molecular analysis*: Faecal pellets and tissue from carcasses should be frozen and sent to the lab for genotyping analysis. All samples should be stored by freezing at -20°C. If a deep-freezer is unavailable, tissue samples in 90% ethanol and faecal samples should first be treated with 90% ethanol before storing them in silica gel at room temperature. Genotyping must be carried out with a marker set optimized for individual identification and must be able to distinguish related individuals (i.e., very low PID_{SIBS}). The identities should match with the genotype database of individuals selected from the conservation-breeding facility for release. If it doesn't, then the genotype database must be searched for potential parents. Faecal pellets should also be examined for physiological stress and disease prevalence (for common pathogens and gastrointestinal parasites).

2.2 Growth phase

This phase starts when the post-release effects on the introduced population are no longer detectable, that is, when a naturally growing population is established in the wild habitat. Consistent camera traps recaptures and regular displacement of individuals could serve as markers for transition to growth phase.

In the growth phase, the release should continue to proceed in order to further augment the wild population, although the release numbers and rate could be adjusted depending on the availability of captive-bred individuals. The acclimatization regime and the captive monitoring protocol would remain unchanged from the establishment phase, but certain modifications must be carried out to the post-release monitoring to reflect the quality of data required to assess a growing

and expanding population. Overall, the post-monitoring regime for this phase would include:

- Surveillance outside the 3 km^2 area using baited camera traps.
- Manual surveys outside the 3 km^2 area for signs of mouse deer activity and carcasses.
- Faecal pellet collection should be carried out in the same manner as the previous phase for molecular identification of individuals and to assess physiological stress and disease prevalence.
- Greater scrutiny of scat of potential predators for signs of mouse deer as prey.

Several protected areas in India have management plans that comprise of regular monitoring of the native fauna. For example, monitoring of threatened indicator species is a primary management objective of the Amrabad Tiger Reserve (chapter 6.3, page 45, Tiger Conservation Plan) and the park's management objectives should be able to cover the requirements of post-release monitoring under the growth phase.

2.3 Regulation phase

This phase starts with the natural stabilisation of introduced population, ascertained by a reduction in growth rate in the monitored population. The release should be stopped when this phase is attained, however population monitoring must continue for potential signs of population decline. The monitoring for this phase should resemble the growth phase and should cover all the areas from where mouse deer presence has been confirmed.

3. Feasibility and Design

3.1 Background biological and ecological knowledge

Mouse deer is a small, shy animal that occurs at low densities. Therefore, not many studies exist on the species. However, sporadic observations of their behaviour and ecology in selected areas and similar studies on other tragulid species provide us with enough background knowledge. Tragulids, including the Indian spotted chevrotain forage on easily digestible food that provide extremely high protein e.g., fallen fruits, seeds, flowers, leaves, shoots, mushrooms. In fact, they are the primary consumers of fallen fruit in the forests they inhabit. Their diminutive physique with arched back and toughened skin enable them to scurry through the dense undergrowth. They are solitary and territorial. They sport large, sabre-like upper canines that they employ to defend territories against conspecifics. They are nocturnal or crepuscular as indicated by their large eyes and prefer to rest during the day. They give birth to one infant at a time and the fawn is left behind in densely vegetated refuge while the mother forages.

Observations of captive mouse deer have also played a key role in elucidating aspects of their behaviour and ecology. For example, studies on the mouse deer population bred as part of Nehru Zoological Park's captive breeding program have revealed their life history parameters like lifespan, age of first oestrus, gestation period and breeding seasonality. They breed throughout the year but show a peak in number of births in the post-monsoon season. Interestingly, they show post-partum oestrus and are capable of conceiving just a few hours after giving birth.

Mouse deer occupy important ecological roles as seed dispersers and serve as prey to several small and large carnivores. There are records of predation by dhole, leopard and forest eagle-owl. Although there have been no observations, it is

likely that mesopredators such as mongooses and honey badgers also prey on mouse deer.

Their reliance on dense undergrowth for forage and as a refuge against predators has led to their increased vulnerability to habitat degradation. Many degraded forests in the Indian subcontinent no longer support mouse deer populations. Moreover, hunting for bushmeat in certain areas has further decimated local populations and driven them to extinction.

3.2 Models and precedents for same/similar species

There have been no reintroductions of mouse deer or other tragulid species into the wild, so there are no precedents to follow. Similar-sized ungulates like the critically endangered suid, pygmy hog in India and the endangered southern pudú in Argentina have been subjects of recent reintroductions, but the evaluation of these programs is still underway. Furthermore, the applicability of these reintroductions to the mouse deer is questionable because of the differences in their behaviour and ecology. The mouse deer, hence, requires a custom-made protocol which could borrow elements from other reintroductions.

3.3 Habitat

The mouse deer inhabits evergreen and deciduous forests across the Indian subcontinent and subsists on a diet of mostly fallen fruits, seeds and foliage. Its habitat use positively correlates with understory complexity and negatively with amount of disturbance. They use dense understory as refuges while resting during the day and to hide from predators. Hence, reintroductions should only take place in undisturbed forests with good understory cover.

3.4 Climate requirements

Mouse deer do not seem to be adversely affected by the climate as long as food resources and shelter are available. They occur in forests that experience a variety of weather patterns, from the moist evergreen forests of the Western Ghats to the dry deciduous forests of central India. Hence, climatic considerations are not important as long as undisturbed native forest habitat is available for reintroduction. However, habitat change can be monitored as part of the management plan for protected areas where mouse deer reintroductions are to be carried, and the data correlated with changes in habitat use by the species.

3.5 Founders and genetic considerations

Since the stock population of this reintroduction program is a captive-bred population, care should be taken not to introduce genetically inbred population. The captive-bred population is derived from several founder individuals of wild-origin from different nearby forests in addition to captive-born individuals from other zoos. Genetic profiling of the captive population must be done to estimate the mean genetic heterozygosity of the captive population. This should be done using a panel of polymorphic microsatellite markers. The same markers can be used during the post-release monitoring to identify individuals using the genotype data. Under no circumstances must the genetic heterozygosity of the captive population be compromised due to the reintroductions. Preservation of genetic diversity of the founder stock must be prioritized. This caveat should inform the choice of individuals to be released.

The genetic heterozygosity of captive mouse deer population in the conservation-breeding program at Nehru Zoological Park was examined using a set of nine

polymorphic microsatellite markers and was found to have a mean observed heterozygosity of 0.625 and mean expected heterozygosity of 0.662 implying a genetically diverse founder stock (report no. CCMB/LaCONES/IMD/86R, dated June 27, 2014).

Since mouse deer is widely distributed across Indian subcontinent and since it's a solitary species, strong genetic structure is not expected to occur in it. This should allow for reintroductions without the fear of potential hybridizations between divergent populations and outbreeding in the reintroduced individuals.

3.6 Disease and parasite considerations

The conservation-breeding facility's proximity to other enclosures in the zoo makes the mouse deer vulnerable to pathogenic infections. The captive individuals must be screened for common pathogens of mouse deer and pathogens afflicting other ungulates housed in the zoo before their release. Diseases like pneumonia and leptospirosis have been encountered in the past five years in the captive-bred mouse deer and other ungulates. Tuberculosis is an endemic in several Indian zoos. Regular monitoring of the captive mouse deer population must be carried out and signs of these diseases must be recorded and communicated to the release facility. Gastrointestinal parasites must also be recorded and individuals with the parasites should not be chosen for release. Regular screening of diseases and parasites should continue over the duration of conditioning process through microscopic and molecular analysis of randomly sampled faecal pellets.

3.7 Legal requirements

Reintroduction programs involve the translocation and release of animals from one area to another. Such activities generally require legal permissions from several authorities. Release in tiger reserves in India, for example, should be permitted by the National Tiger Conservation Authority. Any demands from concerned authorities, e.g., attaining certificates of disease screening of captive individuals from authorized agencies, must be met before the initiation of the reintroduction program. All requisite legal clearances must be acquired before the initiation of the reintroduction program.

3.8 Financial and budget considerations

In order to take the reintroduction program to productive completion, it is crucial to secure the funds necessary to keep it running without a hitch for a minimum of five years. Majority of the funds would be consumed by recurring expenditures to ensure the smooth function of release and monitoring activities. Many of the objectives and actions under the plan, especially monitoring of mouse deer and its habitat, setting up biological laboratories, developing research manpower and setting up of interpretation centres are usually covered under the management plans for protected areas.

An estimate of the expected annual expenses under the plan is as follows:

Head of expenditure	**Amount in lakh Rupees**
Non-recurring*	6.00
Recurring	
Manpower†	4.50
Maintenance‡	2.00
TOTAL	**12.50**

* Laptop, CCTV cameras, solar panels

† Biologist, research assistant, field assistant

‡ Enclosure upkeep, animal feed, fuel

This budget estimate should only serve for a duration of three years from the program's initiation in 2018, after which fresh estimates should be drawn. Each head of expenditure must be recalculated to reflect economic inflation, revised salaries and additional requirements for keeping the program running.

4. Risk Assessment

4.1 Assessing the risk landscape

Assessing the risk landscape is of paramount importance from the perspective of the reintroduction success and the overall health of the habitat chosen for release. Constant monitoring of the risk landscape is necessary for the entire duration of the program, to inform if and when the exit strategy needs to be implemented. The reintroduction areas must be chosen from areas that were known to contain populations of mouse deer natively. Choosing areas that have curtailed and reversed the effects of forest degradation could significantly alter the survival of released individuals.

4.2 Risk to the source population

The source population, that is the mouse deer population in the conservation-breeding facility in Nehru Zoological Park, Hyderabad, has been maintained for over 7 years with no decrease in population count or genetic heterozygosity. Choice of individuals should accommodate the preservation of the genetic diversity in the captive population. Potential risks include outbreak of disease epidemic, hence the need for constant monitoring of the source population.

4.3 Ecological consequences

The ecological consequences of the reintroduction would be more beneficial than detrimental since the species was historically an important component of the ecosystem and its reintroduction would help seed dispersal and serve as prey to native predators.

4.4 Disease risk

The risk of transmitting diseases from the captive population to the wild is very real and has to feature prominently during the screening of potential release animals from the captive facility and during the holding period in the release facility. Related ungulates like chital, sambar and wild boar also share the habitat and would be at risk of disease transmission if infected individuals are released. The plan contains an exit strategy (see section 6.4) that would be applied when diseases are reported in the mouse deer in the conservation-breeding or the soft-release facility, to prevent the risk of disease transmission into wild ungulate populations.

4.5 Invasion risk

Invasion risk by mouse deer are minimal since the species was originally widespread and is only being reintroduced in areas where they were historically present but were extirpated. However, invasion by species hitchhiking on the mouse deer is possible. The holding period under acclimatization stage where they are only fed natively available fruits would ensure that seeds from invasive plants aren't transmitted through faecal pellets. Faecal pellets and other samples collected from the compartments should not be discarded in the vicinity of the release facility.

4.6 Gene escape and interspecific hybridization

There is no risk of gene escape or interspecific hybridization since the mouse deer is a native species and represents a single species, *Moschiola indica*, with no reported subspecies. Moreover, their historical distribution covered the entire subcontinent, hence it is unlikely that mouse deer would have any significant genetic structure.

4.7 Socio-economic risks

As mouse deer is not known to cause any conflict with humans and as the reintroduction sites would be inside protected forest areas, there are no foreseeable socio-economic risks due to this program.

4.8 Financial risks

There are no financial risks involved. Even failure of establishment of reintroduced population would produce rigorously obtained ecological and demographic data that could be used for better scientific planning and management in future reintroductions.

5. Release and Implementation

5.1 Selecting captive-bred individuals for release

The choice of individuals to be released should be based on their fitness measured using the body condition score (Table 2). In brief, only individuals with a body condition score of 7 or above must be selected for release. Capture and release of pregnant individuals should be avoided to reduce stress on the mother and foetus, and to avoid births inside the release facility since infants and juveniles are known to have lower survival probabilities upon release. For these reasons, the release of sub-adults is recommended. Furthermore, sub-adults would have a higher behavioural plasticity compared to adults that have spent considerable amount of time in the artificial environs of the conservation-breeding centre and would be less stressed with and adaptable to the changing conditions. Mouse deer aged between 100 and 120 days old could be chosen. Since the minimum age of first oestrus in females is 145 (Parvathi et al., 2014), this would ensure that the animals aren't pregnant until their release.

5.2 Capture of individuals

Capture of mouse deer from the conservation-breeding facility for transport to the release facility must be done in a manner that causes least harm to the individuals. A method that has been perfected by the animal handlers in the zoo is using jute gunny bags. A large gunny bag is held open by a person on one end of the enclosure while others drive the mouse deer into the bag. The mouse deer readily enters the gunny bag to hide in the dark space. Once the mouse deer enters the bag, it is closed, and the animal is gently secured. Capture of individuals should only be done by experienced personnel only.

5.3 Transportation of individuals

At the end of this process, the chosen individuals should be safely transported to the soft-release facility in a manner that would minimise the stress experienced during the transportation. Each individual should be put in a separate box with a lot of hay to prevent injury. Capture and transport of mother and infant is not recommended, but if it must be done, then the pair should be kept together.

Monitoring stress during the transportation is of utmost importance as acute stress could severely impact the survival of the individuals in a new environment. This should be done by collecting faecal pellets from the individual boxes and quantifying the faecal cortisol metabolites.

5.4 Acclimatization of individuals

The main purpose of the soft-release facility is to house the captive-bred individuals in the facility for as long as they are deemed to be healthy and fit for release. The progress of the conditioning process should be constantly monitored using certain behavioural and molecular indicators. The release facility should have 3 compartments with varying conditioning stages, starting from a conducive environment and ending with a hostile one. The sub-optimal environment should urge the mouse deer to voluntarily leave the release facility in search of better feeding grounds. The first two stages, i.e., stabilization and acclimatization should last at least 14 days, as it would take for the individuals to get used to the new environment and the pre-release stage should not be time-bound but is expected to be as short as possible.

5.5 Release of individuals

The release of the first few batches should ideally coincide with greater food availability. In the Indian subcontinent, this would mean shortly after the onset of monsoon in the region. The rains would also establish a dense forest undergrowth that would serve as refuges for the mouse deer increasing their survival probability.

The number of individuals chosen for release should depend on the availability of animals at the conservation-breeding facility and can vary between releases, but not more than 10 mouse deer should be released in each batch and housed in each compartment of the soft-release facility. However, it is recommended that the ratio of males to female do not vary much. It should ideally range between 4:6 and 6:4 for each release event. This would reduce the probability of any demographic stochasticity acting on a small population.

Since demographic parameters such as mortality rate, survival and growth rate are not known for wild populations of mouse deer, it is difficult to reliably estimate a threshold value for the number of individuals to be released for the successful establishment. However, keeping in mind factors, such as demographic stochasticity and Allee effect, that have a detrimental effect on the survival of small populations, we recommend the release of at least 250 individuals for each release site. These releases should take place within a period of three years from the first release. The releases must be evenly spaced out over four months of the wet season in the site, e.g., June-September or July-October. If the population enters the growth phase before the stipulated time period, the releases shall continue

5.6 Post-release monitoring

The release must be followed by constant monitoring of the reintroduced population using manual surveys, camera traps and molecular methods (see section 2.1.5). The post-release monitoring should continue even after the release ends and till a persistent population is established.

5.7 Evaluation of reintroduction success

Evaluation of the results of reintroductions is critical for the assessment of short- and long-term achievements of the program. With several factors influencing the survival of released animals and success of introduction, there is a need to identify as many as possible within a short amount of time to optimise the strategies for future introductions. It is assumed that individuals in the soft-release facility would not face any predation risk, however any unexpected event must be analysed, and the causes mitigated as soon as possible.

Small populations are, by nature, prone to higher extinction rates. Stochastic processes like demographic and environmental stochasticity can decimate small populations by random fluctuations in birth and death rates. The Allee effect, reduction in growth rate in small populations as a result of higher risks and lower survival, can also play a significant role in the failure of population establishment (Taylor & Hastings, 2005). While stochastic processes cannot be controlled, strong Allee effects can be reduced or prevented by introducing more individuals than the critical size for the species. However, estimation of critical size is extremely difficult and can only be done post-hoc. The preservation of genetic diversity in the surviving population could inform critical size estimates. Alternatively, frequent release of individuals may help negate Allee effect.

Molecular census of live individuals using genotype data and their locations may give us valuable clues about local habitat use preferences that could be used to identify more suitable areas and release sites for future reintroductions. Identification of dead individuals and determination of cause of death also lend substantial information to the decision-making process.

6. Outcome Assessment and Continuing Management

6.1 Pre-release survey and monitoring

There are several preliminary decisions involved with the reintroduction process that may impact the outcome of the process for better or for worse.

- For reintroduction of native species into historical ranges, surveys must be conducted for the suitability of the areas for reintroduction. The surveys must ensure that the areas chosen for the reintroduction process would be conducive for reintroduction through the absence of threats that drove the species to extinction and any potential novel threats.
- Monitoring of the founder population, in this case the captive-bred population, plays a major role in reducing the risks involved with the reintroduction with regards to disease transmission and genetic inbreeding. Individuals chosen for release must not deplete the genetic diversity of the founder population. Once chosen, the individuals must be screened for commonly occurring diseases in mouse deer or other related ungulates from the region. DNA samples must be obtained from all chosen individuals for generating genotype data for post-release monitoring of individual establishment and movement.
- Monitoring the individuals in the release facility during the conditioning process prior to release is perhaps of the most immediate import as it would have bearing on the survival of the released individuals. Surveillance of the individuals should be undertaken by the use of CCTV and camera traps since the cryptic animals are difficult in locate in large-sized enclosure and visual observation would not be possible. The CCTVs and camera traps would further aid in the monitoring the individuals when they are shifted between conditioning stages to ensure none remain behind. Faecal samples must be collected for monitoring physiological stress during the holding period.

6.2 Post-release monitoring

Post-release monitoring of cryptic species like mouse deer with low detection probabilities is a difficult but crucial task. Post-release monitoring data would help in the assessment of successful establishment of individuals, growth rate of introduced population, vulnerability to predation and physiological stress, all of which would inform decisions regarding modification of release parameters. Environmental and habitat parameters must be recorded for each successful sighting or identification of mouse deer outside the release facility. The released individuals should be monitored through multiple available means such as-

- Manual surveys conducted within a 3 km^2 radius initially but expanded later as required to record mouse deer presence (visual sighting or signs like faecal pellets and hoof prints) and to collect faecal samples or tissue from carcasses. (see section 2.1.5)
- Camera traps placed around the release facility to record mouse deer presence, movement and activity. (see section 2.1.5)
- Microscopic analysis of hair from scat of potential predators to estimate survival probability and predation risks. (see section 2.1.5)
- Molecular analysis of faecal pellets for mark-recapture using non-invasive genotyping and for determining if the animals are under physiological stress. (see section 2.1.5)

6.3 Continuing management

Management of the reintroduced population must continue after the goal of the program is achieved. Potential threats must be constantly monitored and any drastic decline in the successfully reintroduced population must be immediately

investigated. Long-term management would also comprise of improving the overall quality of the habitat by facilitating the removal of invasive species and rewilding it with other native sympatric species. For example, rewilding an area of reintroduced mouse deer with megaherbivores like gaur and sambar would considerably reduce predation pressures on the mouse deer. Monitoring of the reintroduced mouse deer population and its habitat could be carried out as part of the overall management of the protected areas which give a lot of importance to the monitoring of major prey species.

6.4 Exit strategy

The reintroduction program should come with a strategy for exiting the program when conditions for the continuation the program as a whole or in specific release sites become unfavourable. The exit protocol should be initiated when certain risk indicators are observed, and it should dictate the actions to be performed.

The problems or risk indicators that should initiate the exit protocol are-

- Failure of establishment of reintroduced population: Failure of establishment due to various reasons after a period of three years from the initial release.
- Disease outbreak in the soft-release facility: The animals kept in the soft-release facility show symptoms of any contagious, debilitating, fatal disease.
- Natural disasters in the release site: Extensive forest fires or deluges and disease epidemics in other ungulates in or near the soft-release sites that would adversely affect the released population.
- Decimation of the soft-release population: Unexpected deaths in the soft-release facility, e.g., entry of a predator in the facility or poisoning of the individuals.

- Threats to the founder population in the zoo: Sudden reduction in the founder population numbers.
- Financial or political instability: Financial or political instability leading to a lack of funds for and threat to the continuation of the reintroduction program.

In case of injuries to or identification of a disease in an individual in the soft-release facility, the individual should be included in the exit protocol. In case of deaths inside the facility, the carcass must be immediately removed from the facility and the remaining animals should be screened for signs of disease through visual observation and microscopic/molecular analysis of faecal pellets. Relevant tissue samples of the dead animal must be collected and preserved for post-mortem analysis. Cryopreservation of germline tissue i.e., testes or ovaries, of mature and immature individuals could be done by freezing in suitable cryomedia (Pothana et al. 2013, Brahmasani et al. 2013). After necessary samples are taken, the carcass must be safely disposed, away from the release site.

The exit protocol must be initiated as soon as the problem is established. Its initiation should not wait for the ascertainment of the causes of the problem. The exit protocol would include the following actions:

- Stopping all further releases from the release site.
- Capture and transportation of living individuals to the zoo or a quarantine facility.
- Defining the problem and ascertaining its causes.

The re-initiation of the reintroduction program should be made only after a thorough examination of the facts leading to the adoption of the exit protocol, and removal of the causal factors. Re-initiation would involve following the action plan from the initial steps.

7. Dissemination of Information

7. Dissemination of information

As part of the program, resources should be dedicated to the dissemination of information regarding the program to the larger scientific and non-scientific community. The former would serve the purpose of critically reviewing the program's progress and establishing the groundwork if there's a need to replicate the program or the methods involved in other similar reintroduction programs. To this end, annual reports from the program summarizing the achievements and setbacks must be submitted to the forest department, the conservation-breeding facility and technical contributors for scrutiny and deliberation.

Engagement with the non-scientific community should be carried out to increase the visibility of the program and awareness about the mouse deer. Sensitization of the public at the zoo and among visitors to the protected area would help them appreciate the immense effort undertaken by the on-field contributors and zookeepers. It would also inform the public about the role played by Nehru Zoological Park and the respective forest department in the *in-situ* conservation of mouse deer.

Moreover, setting up interpretation facilities and public outreach is part of the management plan for most protected areas and zoos. These infrastructures could be used for the purpose of dissemination of information.

Some ways in which the public can be engaged are-

- Development of interpretation centres (dioramas) at the zoo and at the reserve forests where reintroductions have taken place.

- Displaying placards and dioramas about the reintroduction program near the mouse deer enclosures in the zoo, providing details of collaboration with the forest department.
- Displaying placards at the forest department interpretation centres and near check posts informing visitors about mouse deer and about the conservation-breeding and reintroduction programs.
- Producing a short documentary on the planning and implementation of the reintroduction program.
- Engaging with the social media audience with snippets of information about the species and regular updates on the program.
- Creating a logo for the reintroduction program to facilitate dissemination.
- Giving talks in popular public forums.
- Translation into local languages to extend the public outreach.
- Soliciting support from famous public personalities for the program and to provide publicity.

REFERENCES

Basak, K., Ahmed, M., Suraj, M., Sinha, C., Reddy, V. B., Yadav, O., & Mondal, K. (2017). Confirming presence of Indian mouse deer from Chhattisgarh, Central India with photographic evidence after 112 years. *International Journal of Fauna and Biological Studies*, (August).

Brahmasani, S. R., Yelisetti, U. M., Katari, V., Komjeti, S., Lakshmikantan, U., Pawar, R. M., & Sisinthy, S. (2013). Developmental ability after parthenogenetic activation of in vitro matured oocytes collected postmortem from deers. *Small ruminant research*, *113*(1), 128-135.

Eisenberg, J. F., & Lockhart, M. (1972). An ecological reconnaissance of Wilpattu National Park, Ceylon. *Smithsonian Contributions to Zoology*, (101), 1–118. https://doi.org/10.5479/si.00810282.101

Groves, C. P., & Meijaard, E. (2005). Interspecific variation in Moschiola, the Indian chevrotain. *Raffles Bulletin of Zoology*, *Suppl. 12*(12), 413–421.

Hassanin, A., Delsuc, F., Ropiquet, A., Hammer, C., Jansen Van Vuuren, B., Matthee, C., … Couloux, A. (2012). Pattern and timing of diversification of Cetartiodactyla (Mammalia, Laurasiatheria), as revealed by a comprehensive analysis of mitochondrial genomes. *Comptes Rendus - Biologies*, *335*(1), 32–50. https://doi.org/10.1016/j.crvi.2011.11.002

Kamalakannan, M., & Manna, C. K. (2013). Identification of Dorsal Guard Hairs Surface Structure of Indian Chevrotain Moschiola Indica Gray , 1852 (Tragulidae : Artiodactyla : Mammalia), *1*(4), 155–158.

Karanth, K. K., Nichols, J. D., Karanth, K. U., Hines, J. E., & Christensen, N. L.

(2010). The shrinking ark: patterns of large mammal extinctions in India. *Proceedings of the Royal Society B: Biological Sciences*, *277*(1690), 1971–1979. https://doi.org/10.1098/rspb.2010.0171

Kumbhar, A., Prabhu, C. L., Yogesh, J. K., Francies, P., Patwardhan, G., Qureshi, Q., & Jhala, Y. (2013). Application of photographic capture-recapture sampling for estimating abundance of Indian mouse deer Muschiola indica. *World Journal of Zoology*, *8*(4), 388-391.

Madhusudan, M. D., & Karanth, K. U. (2000). Hunting for an Answer: Is Local Hunting Compatible with Large Mammal Conservation in India? *Hunting for Sustainability in Tropical Forests*, 339–355. https://doi.org/10.1016/S0083-6729(08)60838-9

Mein, P., & Ginsburg, L. (1997). The mammals of the Lower Miocene deposits of Li Mae Long, Thailand: Systematics, biostratigraphy and paleoenvironments. *Geodiversitas*, *19*(4), 783–844.

Parvathi, S., Rao, M., Kumar, V., & Umapathy, G. (2014). Observations on reproductive performance of Indian mouse deer (Moschiola indica) in captivity. *Current Science*, *106*(3), 439–441. https://doi.org/10.1007/s10344-012-0676-5.9.

Pickford, M. (2001). Africa's smallest ruminant: A new tragulid from the miocene of Kenya and the biostratigraphy of East African Tragulidae. *Geobios*, *34*(4), 437–447. https://doi.org/10.1016/S0016-6995(01)80007-3

Pickford, M. (2002). Ruminants from the Early Miocene of Napak, Uganda. *Annales de Paleontologie*, *88*(2), 85–113. https://doi.org/10.1016/S0753-3969(02)01041-8

Pothana, L., Makala, H., Devi, L., Varma, V. P., & Goel, S. (2015). Germ cell differentiation in cryopreserved, immature, Indian spotted mouse deer (Moschiola indica) testes xenografted onto mice. *Theriogenology*, *83*(4), 625-633.

Prasad, S., Pittet, A., & Sukumar, R. (2010). Who really ate the fruit? A novel approach to camera trapping for quantifying frugivory by ruminants. *Ecological Research*, *25*(1), 225–231. https://doi.org/10.1007/s11284-009-0650-1

Prasad, S., & Sukumar, R. (2010). Context-dependency of a complex fruit-frugivore mutualism: Temporal variation in crop size and neighborhood effects. *Oikos*, *119*(3), 514–523. https://doi.org/10.1111/j.1600-0706.2009.17971.x

Ramesh, T., Kalle, R., Sankar, K., & Qureshi, Q. (2013). Dry season factors determining habitat use and distribution of mouse deer (Moschiola indica) in the Western Ghats. *European Journal of Wildlife Research*, *59*(2), 271–280. https://doi.org/10.1007/s10344-012-0676-5

Rössner, G. E. (2004). Community structure and regional patterns in late Early to Middle Miocene Ruminantia of Central Europe. *Courier Forschungs-Institut Senckenberg*, *249*, 91–100.

Sánchez, I. M., Quiralte, V., Morales, J., & Pickford, M. (2010). A New Genus of Tragulid Ruminant from the Early Miocene of Kenya. *Acta Palaeontologica Polonica*, *55*(2), 177–187. https://doi.org/10.4202/app.2009.0087

Sánchez, I. M., Quiralte, V., Ríos, M., Morales, J., & Pickford, M. (2015). First African record of the Miocene Asian mouse-deer Siamotragulus (Mammalia, Ruminantia, Tragulidae): Implications for the phylogeny and evolutionary history of the advanced selenodont tragulids. *Journal of Systematic Palaeontology*,

13(7), 543–556. https://doi.org/10.1080/14772019.2014.930526

Sarvani, R. K., Parmar, D. R., Tabasum, W., Thota, N., Sreenivas, A., & Gaur, A. (2018). Characterization of the complete mitogenome of Indian Mouse Deer, Moschiola indica (Artiodactyla: Tragulidae) and its evolutionary significance. *Scientific Reports*, *8*(1), 2697. https://doi.org/10.1038/s41598-018-20946-5

Sridhara, S., Edgaonkar, A., & Kumar, A. (2013). Understorey structure and refuges from predators influence habitat use by a small ungulate, the Indian chevrotain (Moschiola indica) in Western Ghats, India. *Ecological Research*, *28*(3), 427–433. https://doi.org/10.1007/s11284-013-1031-3

Taylor, C. M., & Hastings, A. (2005). Allee effects in biological invasions. *Ecology Letters*. https://doi.org/10.1111/j.1461-0248.2005.00787.x