EAZA Deer Taxon Advisory Group

Best Practice Guidelines

lesser chevrotain

Tragulus javanicus and *Tragulus kanchil*

First edition, 2024

T. ter Meulen, M. Dijkstra, M. van Zijl Langhout, F. Verstappen and K. Groot

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EAZA Preamble

Right from the very beginning it has been the concern of EAZA and the EEPs to encourage and promote the highest possible standards for husbandry of zoo and aquarium animals. For this reason, quite early on, EAZA developed the “Minimum Standards for the Accommodation and Care of Animals in Zoos and Aquaria”. These standards lay down general principles of animal keeping, to which the members of EAZA feel themselves committed. Above and beyond this, some countries have defined regulatory minimum standards for the keeping of individual species regarding the size and furnishings of enclosures etc., which, according to the opinion of authors, should definitely be fulfilled before allowing such animals to be kept within the area of the jurisdiction of those countries. These minimum standards are intended to determine the borderline of acceptable animal welfare. It is not permitted to fall short of these standards. How difficult it is to determine the standards, however, can be seen in the fact that minimum standards vary from country to country. Above and beyond this, specialists of the EEPs and TAGs have undertaken the considerable task of laying down guidelines for keeping individual animal species. Whilst some aspects of husbandry reported in the guidelines will define minimum standards, in general, these guidelines are not to be understood as minimum requirements; they represent best practice. As such the EAZA Best Practice Guidelines for keeping animals intend rather to describe the desirable design of enclosures and prerequisites for animal keeping that are, according to the present state of knowledge, considered as being optimal for each species. They intend above all to indicate how enclosures should be designed and what conditions should be fulfilled for the optimal care of individual species.

Contributors

Our thanks go out to all contributors that helped compile this Best Practice Guidelines by filling out the questionnaires, providing the editing team with pictures and answering supplementary questions.

Summary

The lesser chevrotain (*Tragulus javanicus* & *Tragulus kanchil*) are a member of the family *Tragulidae*. Tragulids or chevrotains are regarded as living fossils, the most ancient representatives of early ruminants. The species is found in the undergrowth of primary and secondary lowland forests of Southeast Asia.

These EAZA Best Practice Guidelines were based on the Husbandry Manual Lesser Mousedeer (second edition, 2010) compiled by A. Semrau, F. Verstappen, M. Wolters, J. Szánthó and M. Hoyer. The data to form the husbandry guidelines was collected through a literature study and a questionnaire in 2007.

These EAZA Best Practice Guidelines were developed with data collected in 2007, 2017 and 2023. New information is provided by the questionnaires of 2017 and 2023. To make sure that old data is not mixed with the recently acquired data, year numbers of newly added information will be mentioned. This way the older data (2007) and newer data (2017/ 2023) are separated. The results of the 2017 questionnaire were kindly provided by R. Lemos de Figueiredo.

These Best Practice Guidelines are composed of two sections. The first provides an overview of biology, ecology and behavior in the wild summarizing published data. The second section provides information on the management of this species in zoos. As it was determined that the official name of the EAZA Ex-Situ Programme is lesser chevrotain, the second section of this Best Practice Guidelines will only refer to lesser chevrotain instead of their other more commonly used name, the lesser mousedeer, as this is the official name for the EAZA Ex-Situ Programme and will refer to both the *Tragulus javanicus* and *T. kanchil*.

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Section I Biology & Field Data Biology

1.1. Taxonomy

The lesser mousedeer is one of the members of the family Tragulidae (infraorder Tragulina, suborder Ruminantia, order Artiodactyla). Tragulids or chevrotains are regarded as living fossils, the most ancient representatives of early ruminants. Traditionally, the family *Tragulidae* is placed between non- ruminating artiodactyls such as pigs and hippos and ruminating artiodactyls like deer, antelope and cattle; systematists consider it a sister-group to the remaining living ruminantia (Figure 1). Until recently, the family Tragulidae (Milne-Edwards, 1864) comprised three genera and four species: the African water chevrotain (*H. aquaticus*; Ogilby, 1841) and the three South-East Asian species Indian spotted chevrotain (*M. meminna* 1; Erxleben, 1777), greater mousedeer (*T. napu*; F. Cuvier, 1822) and lesser mousedeer (*T. javanicus*; Osbeck, 1765) (Groves and Grubb, 1987; Grubb, 1993; Nowak, 1999; Karasov, 2003) (Table 1). The first (Latin) description of 'Cervus javanicus' was given by Osbeck (1757) and translated by Georgi (1765) (van Bemmel, 1949). Astonishingly, more than 200 years later, it is still discussed whether this earliest scientific reference is applicable to a tragulid at all, and the first description of lesser mousedeer is ascribed to Gmelin (1788) (Meijaard and Groves, 2004; Grubb, 2005).

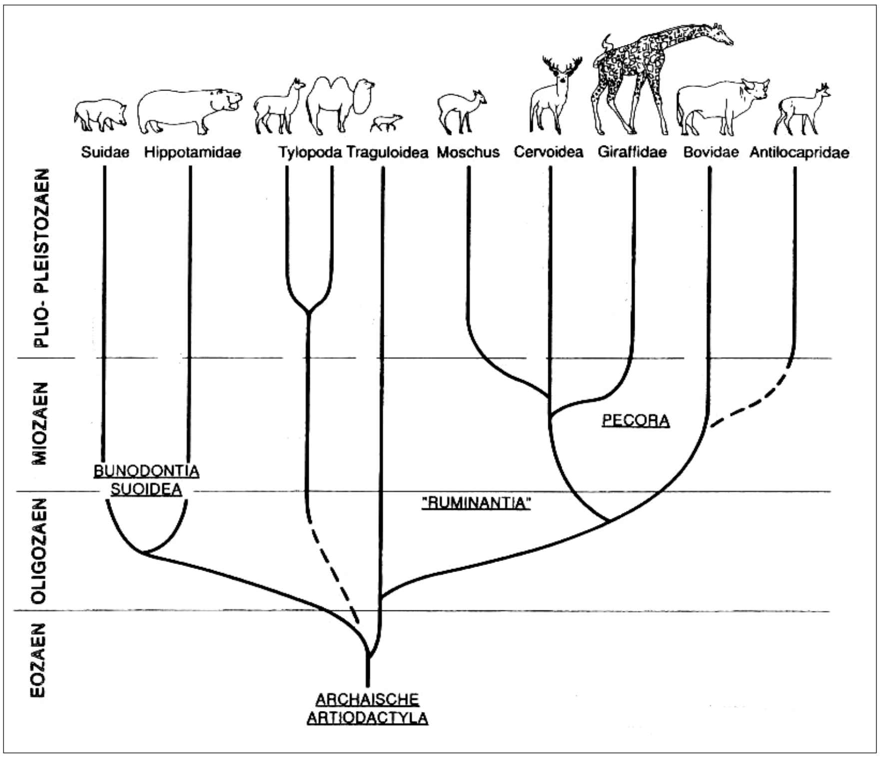


Figure 1. Phylogenetic relationship of the family *Tragulidae* (Starck, 1995; modified).

Order	Artiodactyla	
Suborder	Ruminantia	
Infraorder	Tragulina	
Family	Tragulidae	
Genus	*Hyemoschus*	
Species	*H. aquaticus*	African Water Chevrotain
Genus	*Moschiola*[1]	
Species	*M. memmina*	Indian Spotted Chevrotain
Genus	*Tragulus*	
Species	*T. napu*	Greater Mousedeer
	T. javanicus	Lesser Mousedeer

Table 1. Traditional taxonomic relationship of mousedeer (*Traglulus* sp.) (Nowak, 1999; Grubb, 1993).

During the 18th, 19th and 20th century various zoologists revised in prolixity the taxonomy of the genus *Tragulus* (Brisson, 1762), (e.g. Pallas 1777; Gmelin 1788; Raffles, 1822; Hamilton-Smith, 1827; Milne-Edwards, 1864; Gray, 1872; Stone and Rehn, 1902; Lydekker, 1915; Kloss, 1918; Chasen, 1940; Dobroruka, 1967; Corbet and Hill, 1992; Gentry, 1994); still, a clear key and a general agreement for the determination of species and subspecies amongst the three South-East Asian mousedeer is lacking (Meijaard and Groves, 2004).

The discussion about relationship and classification of the two generally recognized Tragulus-species *T. napu and T. javanicus* is controversial and confusing. Since they strongly resemble each other, Groves (1989) and Endo et al. (2004a) consider *T. javanicus* and *T. napu* as sibling-species. Both species show a remarkable geographical variation; Heck (1968) mentioned 28 subspecies for *T. javanicus* and 28 for *T. napu*. The only clear differences between *T. napu* and *T. javanicus* were said to be color pattern and size, *T. javanicus* having three white lines on the throat, uniformly colored upperparts and being the smaller species versus *T. napu* having a mottled fur, dark lines from eye to nose, light super ciliary lines on the head and being the larger species (van Dort, 1988; Smit-van Dort, 1989; Kim et al., 2004). However, differences in body size were said to be more distinct where the species lived sympatric, whereas in allopatric populations*, T. javanicus* could even be larger than *T. napu.* Differences in skull size were observed by van Dort (1988), Endo et al. (2004b) and Meijaard and Groves (2004). Whereas Endo and colleagues separated skulls of *T. javanicus* by size and shape in three geographic clusters, differentiating mainland an island population, van Dort attributed these differences to the phenomenon of character displacement; where the two species lived side by side differences were more distinct, whereas skulls reached more intermediate size where species lived geographically separated. Smit-van Dort (1989) concluded that the two species are distinguishable only on throat color and metrical characters of metatarsal bones and femurs, i.e.
T. napu having stronger and broader fore and hind feet than *T. javanicus.*

However, after it has long been assumed that the genus *Tragulus* includes only the two species *T. javanicus* and *T. napu* the most recent and most comprehensive taxonomic study by Meijaard and Groves (2004) recognized six species in three species-groups. Based on craniometrical analysis of 338 skulls, some study of coat coloration patterns and geographical distribution, the following species were proposed and adopted (Grubb, 2005; IUCN, 2009) (Table 2).

The napu-group including the species *T. napu* (with the subspecies *T. n. napu, T. n. bunguranensis, T. n. rufulus, T. n. banguei, T. n. neubronneri, T. n. niasis* and *T. n. terutus*) and *T. nigricans.*

The *T. javanicus*-group including the species *T. javanicus, T. williamsoni* and *T. kanchil* (with the subspecies *T. k. kanchil, T. k. abruptus, T. k. siantanicus, T. k. anambensis, T. k. klossi, T.k. hosei, T. k. fulviventer, T. k. ravus, T. k. angustiae, T. k. affinis, T. k. ravulus, T. k. pidonis, T. k. luteicollis, T. k. subrufus, T. k. rubeus and T. k. everetti*).

The monotypic *T. versicolor*-group with the species *T. versicolor.*

[1] the genus *Moschiola* is sometimes treated as a subgenus of *Tragulus* and the species named *T. meminna* (e.g., Starck, 1995; van Dort, 1988; Smit-van Dort, 1989; Nowak, 1999; Karasov, 2003, Groves and Meijaard, 2005).

Table 2. Taxonomic relationship of tragulids (Meijaard and Groves, 2004; Grubb, 2005; IUCN, 2009).

Order	Artiodactyla	
Suborder	Ruminantia	
Infraorder	Tragulina	
Family	Tragulidae	
Genus	*Hyemoschus*	
Species	*H. aquaticus*	Water Chevrotain
Genus	*Moschiola*	
Species	*M. memmina*	White-spotted Chevrotain Indian
	M. indica	Chevrotain
	M. kathygre	Yellow-striped Chevrotain
Genus	*Tragulus*	
Species	*T. napu*	Greater Mousedeer
	T. nigricans	Balabac Mousedeer
	T. javanicus	Javan Mousedeer Lesser
	T. kanchil	Mousedeer
	T. williamsoni	Williamson's Mousedeer
	T. versicolor	Vietnamese Mousedeer

Apart from craniometrics, Meijaard and Groves analysis of different components confirmed that *T. javanicus / kanchil* is separated from *T. napu* primarily by the number of throat stripes, the visibility of the nape line, and the mottling of the upperparts. Equally, Endo et al. (2004a), by sequencing of nucleotides of mitochondrial cytochrome b gene, supported the traditional taxonomical separation between *T. javanicus / kanchil* and *T. napu* by throat colour. Within the species *T. javanicus / kanchil* Endo and colleagues found a high level of phylogeographic structuring. Two major clusters were observed: a primary separation within *T. javanicus / kanchil* was found between individuals from Borneo Island (cluster 1) and those from Peninsula Malaysia and Laos (cluster 2) with a second, moderate level of divergence between southern and northern mainland populations. A third cluster was formed by *T. napu* specimens from Borneo and Pulau Tioman. Speciation among mousedeer and geographic variation were further underlined by a cytogenetic comparison of sex chromosomes of *T. napu* and *T. javanicus* (Kim et al., 2004); polymorphisms occurred not only between lesser and greater mousedeer, but also among lesser mousedeer from different origins.

In summary, depending on their geographical distribution, *Tragulus* species and subspecies of the lesser mousedeer may vary in body size, coat coloration, metrical characters of skull and skeleton, specific nucleotide sequences and morphology of sex chromosomes.

For the purpose of captive management, this Best Practice Guidelines considers the lesser chevrotain a species of both the *Tragulus javanicus* and *Tragulus kanchil* as it is unknown exactly the origins are of the chevrotains the EAZA population. At current, it seems most likely that the taxonomy of the population is *Tragulus kanchil* but this needs to be confirmed through taxonomic research as it can also *be Tragulus javanicus* or *Tragulus williamsoni* (Werner et al., 2019).

1.2. Morphology

Brief Description

The name mousedeer refers to the small size of this rodent- and deer-like ungulate, although it is neither a deer nor a rodent. Measuring only 45-55 cm (18-22 inch) in length (plus 5 cm (2 inch) tail length), 20-25 cm (8-10 inch) in shoulder height and weighing not more than 1.5-2.5 kg (3.3-5.5 lb.), it is said to be the, or one of the smallest artiodactyl(s); following Huffman (2007) the lesser mousedeer and the African royal antelope, (*Neotragus pygmaeus)* are vying for the title of 'the smallest'.

Information about sexual dimorphism in body size of lesser mousedeer are contrasting; whereas Karasov (2003) and Strawder (2000) note that females are smaller than males, the National Research Council (1991) claims that males are smaller than females, Terai et al. (1998) ascertain a higher value in head and body length of fully-grown females, Barrette (1987) notes that females are heavier than males and Ralls (1976) finds that in all small artiodactyls (i.e. tragulids and duikers) females are larger than males.

Overall, a mousedeer's body appears short and compact, the back is rounded and rises towards the rear quarters. The legs are pencil thin. Mousedeer have a small, pointed head, large eyes, rounded ears, and slit-like nostrils. A mousedeer's coat is shorthaired and brown-greyish in color with a large number of variations in tinge. It is darkest on its head and back, while the underside (including belly, inner legs and chin) is white. The throat has a series of white vertical markings. Mousedeer have neither antlers nor horns (Robin, 1988; Nowak, 1999; Karasov, 2003).

Figure 2. Adult Lesser Mousedeer, female in the front and male in the back ARTIS Amsterdam Royal Zoo. Photo courtesy of R. van Weeren.

Physical Characteristics

A mousedeer's pelage is short and thick; Starck (1995) describes the formation of thick hairs to groups of three as a remarkable feature in comparison to other ruminants. Three white vertical markings and uniformly colored upperparts are regarded as a skin characteristic (Smit-van Dort, 1989; Endo et al., 2004a; Meijaard and Groves 2004). Depending on the geographical range, the brown-greyish background color can be lighter or duller and eventually suffused with black, red or orange. It is hypothesized that color variations in mousedeer are a result of genetic changes, such as inbreeding and genetic drift, mainly in island populations (Meijaard and Groves, 2004).

Several authors describe a dermal shield on the rump of tragulids; a thickened area of skin, which presumably protects the lumbal and pelvic region from penetrating wounds (Dubost and Terrade, 1970; Robin, 1979; Wemmer and West, 1982). For *H. aquaticus* this modified hypodermis is described as dense connective tissue fibers running diagonally to the longitudinal axis of the body, alternating regularly and intersecting each other at an angle of ~90°, thereby forming a dense network (Dubost and Terrade, 1970). Robin (1979) confirms the existence of a corresponding structure in lesser mousedeer and reports a light bluish color; Wemmer and West (1982) note a loss of flexibility and a 3-to-4-fold difference in thickness between the hide in the area of rump shield (3-4 mm) and the hide on other parts of the body.

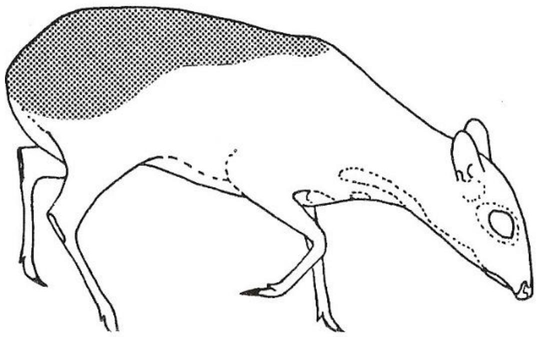


Figure 3. Extension of the dermal shield (Robin, 1979).

Secondary ossification occurs in the lumbal fascia of older males, forming a bony carapace, which covers the pelvis and extends cranially up the thoracic region (Milne-Edwards, 1864; Gray, 1869; Dubost and Terrade, 1970; Robin, 1979; Starck, 1995; Terai et al., 1998).

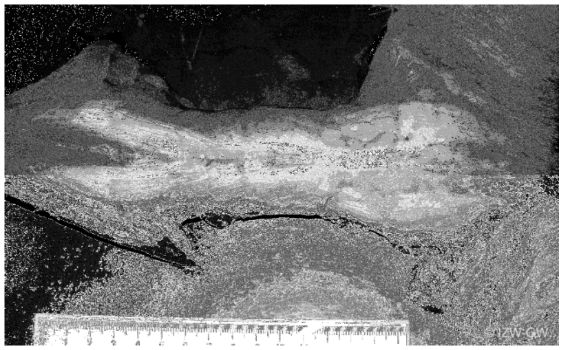


Figure 4. Bony pelvic shield of an adult, male lesser mousedeer to the left: cranial, to the right: caudal: front legs removed (photograph kindly provided by Dr. G. Wibbelt, Leibniz Institute for Zoo and Wildlife Research, Berlin)

Both sexes have an intermandibular gland between the rami of their lower jaws, playing an important role in a mousedeer's territorial and reproductive behavior (Starck, 1995; Karasov et al., 2003; Agungpriyono et al., 2006). Being clearly larger in males (~ 4 cm in length), it makes the profile of a male's head different from that of a female.

The morphology of the gland as well as the composition of the secretion emerging from its pores have been investigated in detail by Agungpriyono et al. (2006). Briefly, the gland is composed of mainly holocrine, sebaceous but also apocrin glandular material. The secretion appears to be a mixture of large amounts of lipid material from sebaceous glands, but also glycoconjugates secreted by both sebaceous and apocrin glands. Apart from a sexual dimorphism in size of this gland, Agungpriyono and colleagues note that the secretions of male mousedeer also differ in their composition of glycoconjugates from those of females.

Figure 5. Intermandibular gland of an adult male.

Mousedeer do not have facial or foot glands, but in connection with elements of their marking behavior, Robin (1979) describes the existence of different formations of glandular tissues in the area of the rectum, anus, latero-ventrally of the tail and at the males' prepuce.
Females have four inguinal mammae, grouped in a small udder between the hind legs (Kamis, 1994; Starck, 1995; Nowak, 1999; Karasov, 2003).

From the outer appearance, the small skull of a tragulid is characterized by a rather straight axis, a pointed snout, the absence of horns or antlers and remarkably wide orbitae. As already mentioned in chapter 1.1, there is an enormous geographic variation in skull size and shape of mousedeer of different origins, which only recently lead to a taxonomical revision of the genus Tragulus (van Dort, 1988; Smit-van Dort, 1989; Endo et al., 2004b; Meijaard and Groves, 2004; Grubb 2005).

The permanent dental formula is 0 1 3 3 / 3 1 3 3 (0 1 3 3 / 4 0 3 3). Whereas the upper canines are small studs in females, they are sharp and tusk-like in males, protruding down- and backwards from the mouth. As further characteristic features of a mousedeer's skull shall be mentioned: older males develop a crista sagittalis (denied by Terai et al., 1998), the bulla tympanica is inflated and filled with cancellate bony tissue, there is no fossa glandulae lacrimalis, only one lacrimal orifice, no fossa sacci lacrimalis and no anteorbital vacuity; the nasal cavity is described as being relatively large and equipped with five endoturbinals; neither the angles of the mandible nor the coronoid process appear well developed (Milne-Edwards, 1864; Vidyadaran et al., 1981; Smit-van Dort, 1989; Starck 1995; Terai et al., 1998; Nowak, 1999).

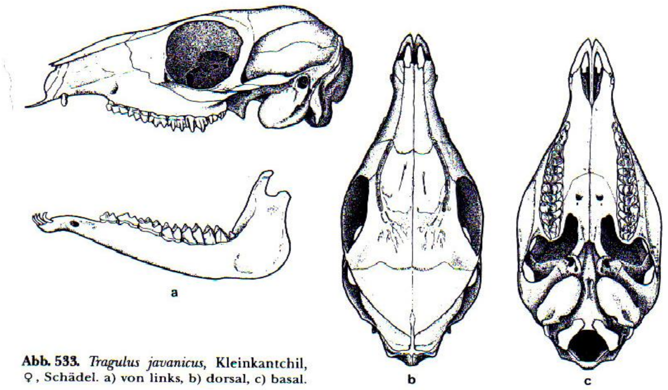
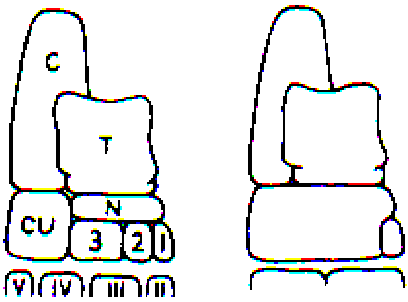


Figure 6. Skull of a female lesser mousedeer; a) lateral b) dorsal and c) basal view (Starck, 1995, modified).

The vertebral column consists of 7 cervical, 13 thoracic, 6 lumbar, 5 sacral and up to 13 coccygeal vertebrae (Milne-Edwards, 1864; Starck, 1995); a foramen vertebrale laterale atlantis as canal for the vertebral artery is said to be missing in *T. javanicus* and *T. napu* (Smit-van Dort, 1989), the dens axis is described being flattened as in Suidae (Starck, 1995). As in other ungulates a clavicle is absent, but a thin long ligamentous or connective tissue is present (Rocha-Barbosa, 2002). Milne-Edwards (1864) and Smit-van Dort (1989) list the existence of a foramen supratrochleare in mousedeer as a specialty of the distal humerus.

Regarding the foot as the principal distinguishing feature of the order artiodactyla: a lesser mousedeer's metacarpalia and – tarsalia III and IV are fused to the so called 'cannon bone', whereas the metapodia II and V are present as short and slender splints. It appears noteworthy that Starck (1995) regards the fusion between the metapodia III and IV as incomplete. At the carpus, the ossa capitatum and trapezoideum (eventually also the os trapezium) are fused, at the tarsus, the ossa cuboideum, naviculare and cuneiforme intermedium and laterale. The hind legs are elongated compared to front legs (Milne-Edwards, 1864; Smit-van Dort, 1989; Starck 1995; Karasov 2003). The delicate feet of mousedeer make it difficult to find footprints; still, the animal's track is described as a "V" open at the base, the individual slots being wedge-shaped and 1.5 - 2 cm in length (Kamis et al., 1994).

Figure 7. A lesser mousedeer's metacarpus a) dorsal and b) ventral view (Starck, 1995; modified).



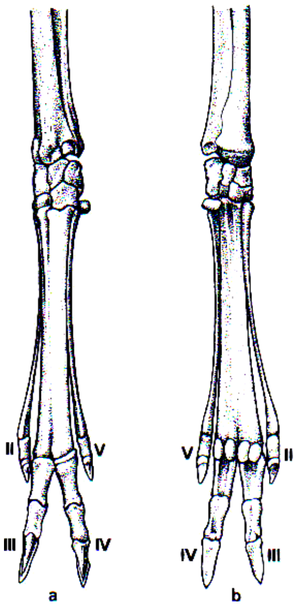


Figure 8. A lesser mousedeer's tarsus (Starck, 1995; modified); left: schematic drawing of tarsal bones, right: tarsus of a Lesser Mousedeer, (C=calcaneus, T=talus, N=os naviculare, CU=os cuboideum, 1,2,3=ossa cuneifome mediale, intermedium et laterale, II-V=ossa metacarpalia.

Amongst artiodactyls, tragulids have the least developed cerebrum; thus, in contrast to many other mammals, tectum and cerebellum are dorsal not covered by the occipital lobe of the cerebrum. A mousedeer's brain appears pear-shaped in the dorsal view (Figure 9), rather flat in the lateral view and displays only minor tendency for cleavage. Whereas a sulcus / fissura lateralis cerebri (syn. fissura sylvia) is said to be missing, all other major and constantly in a mammal's cerebrum occurring sulci are clearly visible (Starck, 1995).

Detailed information on the morphology and species-specific correlation between body- and brain-weight of tragulids can be found at Sigmund (1981). Amongst senses, smell and vision with the according centers are said to be dominant (Starck, 1995). A comparative study on topography and distribution of retinal colour-specific receptors in various artiodactyls was undertaken by Schiviz (2006).

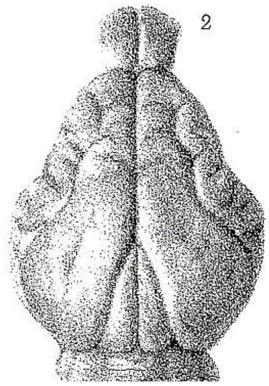


Figure 9. Dorsal view of a mousedeer's brain (Milne-Edwards, 1864).

The lesser mousedeer has a small, pointed mouth with a narrow lower jaw and a wider upper jaw (anisognathus), which results in the occlusal surfaces of the teeth being not in full occlusion, but in a pattern of ridges of one tooth alternating with the corresponding depressions of the opposite tooth. The deciduous dental formula of mousedeer is (0 1 3 / 3 1 3) x 2 = 22 (Vidyadaran et al., 1981), the permanent dental formula is (0 1 3 3 / 3 1 3 3) or (0 1 3 3 / 4 0 3 3) x 2 = 34 (Vidyadaran et al., 1981; Smit-van Dort, 1989); the lower canine is incorporated into the row of incisors. Instead of incisors mousedeer have a dental pad in the upper jaw. Upper canines are present in both sexes, but whereas they form only mere stubs in females they are prominent, mediolaterally flattened and pointed in males. From the first premolar tooth canines are separated by a fairly wide diastema. Premolars are sectorial in type, have a distinct neck, two or three ridges and well-developed roots. Vidyadaran et al. (1981) concluded that they are suited more for piercing and chopping rather than grinding and chewing as is the case in the premolars of higher ruminants. Molar teeth in contrast resemble those of higher ruminants with four or five crescent-shaped ridges (selenodont) for efficient grinding of plants.

Measuring about 5 cm in length, the tongue of a mousedeer is relatively long, thus a useful organ for feeding, tasting, and grooming. Tongue and lingual papillae were studied in detail by Agungpriyono et al. (1995a), who found some characteristics that differed from those of pecoran ruminants, e.g., the absence of a torus and fossa linguae and mechanical conical and lenticular papillae, a weak keratinization of the epithelium covering the filiform papillae, and the presence of foliate papillae. Functional and morphological peculiarities observed in the mastication muscles of mousedeer (Endo et al., 2002), such as e.g., a dissimilar movability of the mandible, underlined a dietary adaptation as much as dissections on salivary glands, carried out by Vidyadaran et al. (1994). The parotid gland appeared lobulated, relatively large, and differed in shape and extent from those of domestic ruminants. The mandibular gland was not distinctly lobulated and partly covered by the parotid gland. The mean weight of salivary glands relative to the body weight of mousedeer were ascertained as 2.28 +/- 0.5% for the parotid and 1.24 +/- 0.29% for the mandibular gland.

The stomach of mousedeer consists of only three compartments; an omasum is absent, but a vestigial area is present. The stomach complex occupies almost the whole abdominal cavity from the diaphragm to the pelvic inlet, with considerable portions of rumen, reticulum and abomasum extending to the right of the median plane. The gross morphology of the stomach is described as follows: briefly, the rumen resembles a three-quarter S-shape, spirally twisted with a large ventral and caudoventral sac. The dorsal sac overlies the ventral sac pushing it caudally. The caudoventral blind sac is extensive and placed caudodorsal to the ventral sac. A caudodorsal blind sac is inconspicuous. The mean volume of the rumen was ascertained as ~380 ml or 88% of the volume of the total stomach, the mean surface area of the rumen as ~140 cm2 or 78% of the total surface area of the stomach. At the cranial end of the ruminal cavity lies a wide rumino-reticular orifice, bounded by an extensive rumino-reticular fold. The reticulum is larger than the ventrally lying, bent abomasum and shows a distinct reticular groove; mean volumes of reticulum and abomasum were ascertained as ~35 ml for the reticulum and ~17 ml for the abomasum (~8% resp. ~4% of the total stomach volume), mean surface areas as ~20 cm2 for the reticulum and 18.5 cm2 for the abomasum (~11% resp. ~10% of the total stomach surface area) (Vidyadaran et al., 1982).

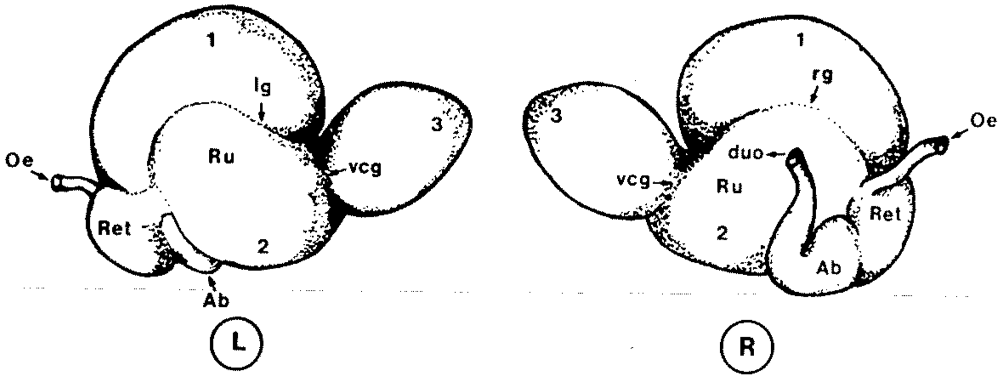


Figure 10. An illustration of the stomach of the Lesser Mousedeer (Agungpriyono et al., 1992, modified); L: left view, R: right view; Ru: rumen, Ret: reticulum; Ab: abomasum; duo: duodenum; Oe: oesophagus; 1: dorsal, 2: ventral and 3: caudoventral blind sac; lg: left longitudinal groove, rg: right longitudinal groove, vcg: ventral coronary groove.

Internally, four not well-developed pillars are described in the rumen: cranial, caudal, longitudinal, and ventral, each of them corresponding to an external groove The internal surface of the rumen is throughout well covered by flat, leaf- and / or tongue-like papillae, which vary in size and density. The internal surface of the reticulum appears as a honeycomb, each cell of which has four, five or six sides, the largest found ventrally, and the floor of each cell being studded with cornified conical papillae. Reticular cells of mousedeer examined were only sparsely subdivided by secondary/tertiary crests. Although an omasum is undifferentiated in mousedeer, a small, narrow transition zone with low mucosal folds can be found between reticulum and abomasum. It is said to represent the vestigial omasum. The internal view of the abomasum is characterized by six or seven low and thick spiral mucosal folds running longitudinally in the fundus. Some transverse folds connect the longitudinal ones.

Histologically, the mucosal surface of rumen, reticulum and transition zone is lined with a stratified squamous epithelium and that of the abomasum with a simple columnar type. The epithelial keratinization is weak in rumen, floor of the reticular groove and transition zone, while it is strong in the leaving parts of the reticulum.

A thin but continuous layer of muscle actin-immunoreactive cells was demonstrated in the ruminal mucosa while the muscularis mucosae of the reticulum was well- developed. The transition zone appears as a nonglandular area having low mucosal folds and two layers of muscularis mucosae. The abomasal mucosa was characterized by cardiac, proper gastric and pyloric glands. Fourteen different types of endocrine cells were detected immunohistochemically in the gastrointestinal mucosa of mousedeer showing a distribution pattern, suggested to be more similar to that of pigs than to that of cattle or sheep (Agungpriyono et al., 1992, 1994, 1995b).

The complex of small and large intestines usually occupies the caudodorsal abdomen but shows extreme mobility. The caecum is relatively wide, without any taenia or haustra. Carcass dissection studies showed that mousedeer have a relatively high ratio of gut mass to total live mass (>25%).
The **liver** is multilobed and a gall bladder is present; both can be found on the right side of the dominant stomach complex (Vidyadaran et al., 1982).

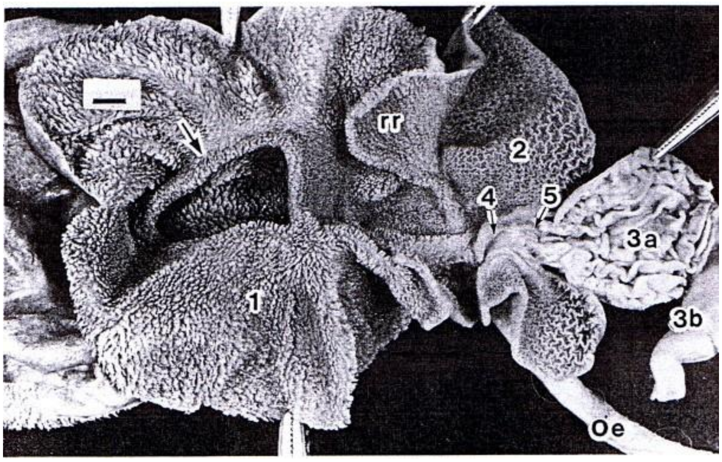


Figure 11. Mucosal surface of forestomachs and abomasum of a lesser mousedeer (Agungpriyono et al., 1992, modified); 1: dorsal sac of the rumen, 2: reticulum, 3a: fundic part of the abomasum, 3b: its pylorus, 4: reticular groove, 5: transition zone, Oe: oesophagus, arrow: longitudinal pillar, rr: ruminoreticular fold, bar: 5 mm.

A special feature within the circulatory system of lesser and greater mousedeer is described by Fukuta et al. (2007): the absence of a rete mirabile epidurale. This intracranial carotid rete is described as a unique blood vascular system generally supplying the brain of artiodactyls with an absent or involuted internal carotid artery. In mousedeer as in non-artiodactyls, such as canines, equines and humans, a complete internal carotid artery supplies the brain.

Kidneys are simple bean-shaped and not lobed, although a superficial cleavage may be visible (personal communication Dr. G. Wibbelt, Leibniz Institute for Zoo and Wildlife Research, Berlin). The cranial pole of the right kidney is abutting the caudate lobe of the liver, the left kidney lies adjacent but immediately caudal to it (Richardson et al., 1988a, b).

The most recent and detailed characterization of female reproductive organs of mousedeer is provided by Kimura et al. (2004). Briefly, ovaries and oviduct are very similar to that of other ruminants, but the ovary of pregnant mousedeer appears directly attached to the uterine wall, without any mesovarium.

Ovarian medulla and cortex are clearly differentiated, and primordial follicles evenly distributed, mainly in the outer cortex. Follicles normally contain one, very occasionally two, oocyte(s). The epithelium of follicles consists of epithelial (granulosa) and two layers of thecal cells. Irrespective of their gestational period large corpora lutea and mature follicles were observed in the ovaries of pregnant individuals, confirming the possibility of a postpartum oestrus and close consecutive pregnancies.

With immunohistochemistry, the potential for progesterone production in the luteal cells was observed; it is not yet known whether the corpus luteum of mousedeer secretes progesterone throughout gestation or whether there is a transfer of the production site to the placenta later in pregnancy. Mousedeer have a uterus bicornis, with a supposed genetically based asymmetry in size of left and right uterine horn (R>L). The uterine epithelium consists of columnar cells, with well-developed uterine glands throughout the lamina propria. During the study by Kimura and colleagues all fetuses were found in the right uterine horn of pregnant females.

The presence of large corpora lutea in the left ovary of some of these females was seen as indicative for the possibility of internal migration of the embryo. A mousedeer's placenta was described as being diffuse, with no evidence of caruncular or placentomal differentiation (Strahl, 1905; Starck, 1995; Soma, 2004; Kimura et al., 2004). Strahl (1905) defines a semiplacenta diffusa incompleta, due to areas with no villi on the anti-mesometrial side of the pregnant uterus. Histologically, endometrial tissue and trophoblastic layers were intimately associated, but did not show obvious branching; interestingly, characteristic ruminant chorionic binucleated cells were found in the trophectodermal villi (Kimura et al., 2004). In contrast to Soma (2004) and Starck (1995), who state that a mousedeer's placenta is typical epitheliochorial, Kimura and colleagues suggest that the placenta of tragulids is a transitional type between diffuse epitheliochorial and polycotyledonary synepithelial.

Gross anatomical features of male genital organs and accessory glands were described by Vidyadaran et al. (1999). Briefly, the penis is of the fibroelastic type, lacks a prominent glans and is coiled at its free end. Near the tight coil of the penis lies a U-shaped ventral process. The scrotum is prominent, unpigmented, devoid of hair and attached close to the body, high in the perineal region. The ovoid testes are obliquely orientated. Since male mousedeer studied showed a large caput and cauda epididymis, seasonal changes in size cannot be excluded.

Figure 12. Coiled penis of a lesser mousedeer, Photo courtesy of Dr. R. Hermes, Leibniz Institute for Zoo and Wildlife Research, Berlin).

Andriana et al. (2003a, 2003b, 2005) performed an ultrastructural study on Leydig and Sertoli cells of mature and immature lesser mousedeer. A multivesicular nuclear body, which is said to be specifically present in the Sertoli cell nucleus of ruminants, was infrequently observed, but peculiar bundles of actin and intermediate filaments were frequently detected in the nucleus resp. the cytoplasm of Leydig cells of mature mousedeer. Accessory glands consist of paired and well-defined vesicular and bulbourethral glands, whereas the prostate gland was only observed as a small, flat mass on the surface of the pelvic urethra (Vidyadaran et al., 1999).
Twenty-four semen samples, collected by electroejaculation from 13 lesser mousedeer, were evaluated by Haron et al. (2000). Semen was creamy, milky, pale yellowish, or watery and mean values for characteristic parameters were ascertained as follows:

- Ejaculate volume 23.7 +/- 2.5 al
- Sperm concentration 366.9 +/- 127.8 x 10^6 spermatozoa/ml
  9 +/- 3.4 x 10^6 spermatozoa/ejaculate
  (Colour and sperm concentration were positively correlated; semen with creamy colour had the highest, watery semen the lowest sperm count)
- Sperm motility 40.4 +/- 3.1 %
- Sperm normality 71.4 +/- 1.6 %
- Sperm viability 59.6 +/- 2.1 %
- pH 7 - 8

The gross morphology of mature spermatozoa resembled that of domestic ruminants, with an oval head, a midpiece, and a tail. During the study of Haron and colleagues 28.8% of spermatozoa showed morphological defects, such as e.g., double heads, double midpieces or looped tails. Authors concluded that electroejaculation is a safe way for collection of ejaculates in lesser mousedeer, but stated that, referring to the values of volume and sperm defects, additional study is warranted.

The chromosome number of mousedeer is 2n = 32, consisting of 15 metacentric autosome pairs and X and Y sex chromosome pair (Starck, 1995; Gallagher et al., 1996; Soma, 2004; Kim et al., 2004). Sex chromosomes showed polymorphisms in size and morphology between *T. napu* and *T. javanicus* and among *T. javanicus* from different origins; 18S-28S rDNA of sex chromosomes varied not only in size, but also in their distribution patterns on the sex chromosome (Kim et al., 2004). It is suggested that chromosomal changes may reflect the relationship between the geographic distribution and speciation among mousedeer. The phylogeographic structure of Lesser and Greater Mousedeer on a genetic level was also point of interest of Endo et al. (2004a), who, by examining sequence data of mitochondrial cytochrom b gene, found three major clusters with further subdivision within the genus *Tragulus*.

Several authors have undertaken phylogenetic analysis of the order *Artiodactyla* resp. the suborder *Ruminantia* on a molecular level, thereby including the genus *Tragulus*: κ-casein and cytochrom b sequences were determined by Chikuni et al. (1995), the evolution of cytochrome b gene studied by Irwin et al. (1991), karyotypes of different artiodactyls were compared by Gallagher et al. (1996), the gene encoding pituary growth hormone was characterized by Wallis and Wallis (2001), and secretory ribonucleases were investigated by Breukelman et al. (2001). Hassanin and Douzery (2003) at last analyzed a data set including several mitochondrial and nuclear markers; all results verify the phylogenetic ancient origin of mousedeer.

1.3. Physiology

Digestive Physiology

Lesser mousedeer are ruminants. Based on feeding patterns and the morphology and physiology of their gastrointestinal tract it was concluded that they tend to be 'frugivorous ungulates' (Heydon and Bulloh, 1997), 'selective feeders' (Medway, 1983; Nolan et al., 1995; Karasov, 2003; Farida et al., 2006), 'browsers' (Kay et al., 1979; Endo et al., 2002), 'highly selective browsers' (Janis, 1984) or 'concentrate selectors' (Kay et al., 1979; Hofmann, 1988; Vidyadaran et al., 1994; Agungpriyono et al., 1992, 1995).

From the viewpoint of rumen microbiology lesser mousedeer are regarded as unique (Kudo et al., 1995, 1997); briefly, rumen content of mousedeer was found like a thick slurry, much more solid than in large domestic ruminants, with a pH range from 5.5 to 6.5. Active cellulytic bacteria were present (e.g., *Fibrobacter succinogenes*, *Ruminococcus albus* and *R. flavefaciens*), essential for the breakdown of fibrous jungle forages composing a mousedeer's natural diet. Furthermore, fairly large motile bacteria, similar to *Oval* and *Oscillospira* were seen in large numbers. Kudo et al. (1995, 1997) and Imai et al. (1995) detected six species of ciliate protozoa belonging to two genera: *Isotricha jalaludinii*, *Entodinium simplex*, *E. dubardii*, *E. anteronucleatum*, *E. nanellum* und *E. convexum*. Moreover, in *M. meminna* (*T. meminna*) the presence of ciliate protozoa belonging to the genera *Diplodinium*, *Eudiplodinium* and *Epidinium* was reported. The average number of ciliate protozoa in mousedeer was about 4.6 x 10^5/g of rumen content, a similar value as recorded in healthy domestic animals. Except for Isotricha (*I. jalaludinii.* was assigned to a new species at that time by Imai and colleagues), all species of protozoa were similar to those of domestic ruminants, only the general ciliate composition was judged as being poor compared to domestic ruminants. Often, the occurrence of a mono-fauna of protozoa, *Isotricha* ssp. or *Entodinium* ssp. alone, and sometimes a total absence of protozoa has been observed. There are, so far, no reports about the presence of fungi in a mousedeer's rumen content (Kudo et al. 1995, 1997).

Table 3. Ruminating and eating behavior of lesser mousedeer (Nordin, 1978a).

	A. High grain ration	B. High fiber ration	C. Control diet
Composition of the diet (g) DM			
Peanuts	7.4	7.4	7.4
Long beans	4.9	4.9	4.9
Kangkong	2.0	6.0	2.0
Orange	2.5	5.0	2.5
Banana	13.4	18.5	25.2
Papaya	2.2	3.4	3.4
Maize	13.0	-	-
Comparative cellulose content (%)	84	130	100
Total rumination periods per day	20.94 ± 0.98	20.00 ± 0.52	15.83 ± 1.02
Total rumination time (min/day)	73.19 ± 4.09	69.03 ± 5.61	51.53 ± 3.34
Chews per bolus	15.9 ± 0.72	13.1 ± 0.76	11.6 ± 0.47
Rumination time per bolus (sec)	9.9 ± 0.64	8.5 ± 0.39	7.8 ± 0.25
Rumination chews per min	96.6	92.4	90.0
Total eating time (min/day)	20.7 ± 1.63	25.4 ± 2.26	19.7 ± 1.01

For effective mechanical breakdown of roughage and thereby enlargement of substrate surface area for fermentative processes, mousedeer, like all ruminants, regurgitate larger particles into the mouth, re-chew and re-swallow them. Rumination was seen as well in standing as in resting position (Ralls et al., 1975; Robin, 1979). Nordin (1978a) investigated eating and ruminating behavior of captive mousedeer by giving different diets, either high in grain or high in fiber, in comparison to a control ration, which at that time was commonly fed to captive mousedeer. Fed the control ration, animals spent ~20 min per day eating and ~50 min per day ruminating (table 3). Changes in ration composition were accompanied by changes in eating and ruminating behavior.

Table 4: Voluntary food intake and digestion of lesser mousedeer (Nordin, 1978a).

	A. High grain ration	B. High fibre ration	C. Control diet
Dry Matter Intake (g) / day	42.5	42.2	43.2
Digestibility of			
- dry matter	90.8 %	92.0 %	92.4 %
- organic matter	91.9 %	92.8 %	93.2 %
- cellulose	90.3 %	94.5 %	93.7 %
- energy	89.7 %	91.2 %	91.3 %
Mean retention time (h)	43.1 ± 3.3	45.0 ± 3.03	42.7 ± 2.04

The mousedeer spent more time eating the high fiber ration and more time ruminating on both the high grain and high fiber rations. Each bolus was chewed longer and more thoroughly on both rations and a higher rate of chewing occurred with added grain. Fiber is known to induce rumination by tactile stimuli, but in this study maize grain was more effective than fiber in inducing rumination. Although the grain ration contained significantly less fiber than the control ration it induced more rumination than even the high fiber ration.

Food intake and digestibility characteristics of the small ruminant lesser mousedeer were point of interest of several experimental studies; some figures providing information on a mousedeer's digestive physiology are summarized in table 4 and 5.

In summary, the lesser mousedeer digests its food well; changes in food composition are compensated for by changes in its digestive physiology and behavior to ensure efficient digestion (Nordin, 1978a). The level of voluntary food intake by lesser mousedeer ranged from around 30 up to more than 50 g DM/day depending on the ration's composition. Apparent digestibility of nutrients was sufficiently high in all formulations. However, Nordin (1978a) observed superior digestion when the ration consisted of six or seven constituents compared to just two constituents. Within the limits of fiber content in the rations Nordin (1978a) used in his study, additional fiber did not influence the digestibility, but the animal compensated by increasing the retention time of the diet. Nordin (1978b) and Kay (1987) concluded that, like other small ruminants, the lesser mousedeer has high energy requirements per unit body weight, which must be met by selection of a very digestible diet. Still, Nolan et al. (1995) showed that mousedeer can increase feed intake on less energy-dense diets in order to maintain adequate energy levels, although digestibility coefficients were much lower when animals were fed only Lundai foliage. The animals' urinary allantoin secretion was low relative to that of other ruminants (in this study sheep); whether the microbial yield is generally low in this species or whether they excrete other purine derivatives is unknown (Nolan et al., 1995).

[2] Kay (1987) corrected the DE intake ascertained by Nordin (1978) due to the high energy content of peanuts

Table 5. Parameters on food intake and digestibility from different experimental studies.

Parameter				
Dry Matter Intake / day	55.5 g or 42.4 g/kg $M^{0.73}$ or 3.7 % *M*	33.4 g or 26.1 g/kg $M^{0.75}$ or 2.4 % *M*	29.9 g or 23 g/kg $M^{0.75}$ or 2.2 % *M*	33 g or 25.6 g/kg $M^{0.75}$
Digestible Energy Intake / day	853 kJ/day or 627 kJ/kg $M^{0.73}$	59.8 kcal/day or 45.6 kcal/kg $M^{0.75}$ * 127 kcal/day or 91 kcal/kg $M^{0.75}$ **	-	-
Metabolisable Energy	571 kJ/ $M^{0.73}$	-	-	-
Digestibility of				
- organic matter	83.8 %	88.2 %	-	-
- crude fibre	63.7 %	85.6 %	-	-
- acid detergent fibre	60.5 %	-	-	-
- neutral detergent fibre	72.1 %	-	-	-
- crude protein	65.0 %	88.9 %	-	-
Urinary Allantoin Secretion	0.05 mg/g DM	-	-	-
Mean Retention Time	-	-	52.8 hrs	26.5 hrs
Source	Nolan et al., 1995	* Nordin, 1978b; ** Kay, 1987 [2]	Paden and Nordin, 1978	
Composition of the diet	500 g of fresh Lundai foliage (*Sapium baccatum*)	20 g peanuts and kangkong (*Ipomoea reptans*) ad libitum	20 g peanuts and kangkong(*Ipomoea reptans) ad libitum* + 20 g *stained sorghumgrain (Sorghum bicolor)*	20 g peanuts and kangkong (*Ipomoe reptans*) ad libitum + 20 g marked rabbit pellets

Energy Metabolism

To gain further insights into feeding requirements of mousedeer, Darlis et al. (2001) determined heat production in relation to activity in an open circuit respiration chamber. Briefly, male mousedeer consumed more dry matter, organic matter, and gross energy than females (Table 6). Discriminating the three activities eating, standing, and sitting, the time spent sitting was significantly longer than the time spent standing or eating in both sexes, but female mousedeer tended to spend a longer time period sitting than males. Most activities (standing or eating) occurred during daytime (8.00-20.00 h). Heat production per minute was highest during eating (0.44 and 0.43 kJ/kg W0.75/min for male and female, respectively), followed by standing and sitting, whereas heat production expressed as kJ per day was highest for sitting (227.2 and 238.6 kJ/kg W0.75/day for male and female, respectively), followed by standing and eating. Heat production rates obtained over a 24h period was in both sexes significantly higher in the morning to afternoon (8.00-14.00 h) and afternoon to evening period (14.00-20.00 h), than those during the night (20.00-2.00 h) and the early morning periods (2.00– 8.00). Between 8.00 and 20.00 h heat production was significantly higher in males than in females.

Table 6. Parameters on food intake, comparing male and female lesser mousedeer (Darlis et al., 2001); animals were fed kangkong (Ipomoea aquatica), sweet potato (Ipomoea batata) and commercial rabbit pellets ad libitum.

Intake	Male	Female
Dry Matter [g/kg $W^{0.75}$/day]	43.8 ± 2.1	37.7 ± 0.5
Organic Matter [g/kg $W^{0.75}$/day]	38.4 ± 1.7	33.1 ± 0.4
Crude Protein [g/kg $W^{0.75}$/day]	6.8 ± 0.4	5.8 ± 0.1
Gross Energy [kJ/kg $W^{0.75}$/day]	748.3 ± 34.6	645.3 ± 8.6

Water Metabolism

Parameters of water metabolism in lesser Malayan mousedeer are reported by Kamis (1981)3* and Nolan et al. (1995)4*: water was estimated to represent about 70* / 77** % of their total body weight, which means that only about 23 to 30 % are solid. These findings were consistent with carcass dissection studies, that showed that mousedeer have a relatively high ratio of gut mass to total live mass (>25 %), a high percentage of muscle (~84 %), less than 1 % fat and connective tissue and a low percentage of bone (~15 %) (Vidyadaran et al., 1983). Daily water intake was, on average, 312* resp. 258** ml/day. The greater part of the water entering the body of mousedeer was ingested by food, a smaller fraction was drunk (interestingly, mousedeer drink by lapping up water with their tongue like cat and dog (Kudo et al., 1997). Mean water turnover was an average of 203*resp. 182** ml/kg0.82/day. Losses of water from the body occurred via urine, feces (a relatively small fraction, due to the production of usually dry, well-defined pellets), and evaporative via lungs and skin. The biological half-life of water in mousedeer was ascertained as in average 2.8 days. Findings regarding the water metabolism in mousedeer were consistent with findings in other tropical mammals (Kamis, 1981; Nolan et al., 1995).

Body Temperature & Temperature Regulation

The mean rectal temperature of lesser mousedeer was ascertained as 38.4°C, with their thermoneutral zone lying between 26.6 and 29°C (Whittow et al., 1977). Rectal temperatures were relatively constant in ambient temperatures of 15–30°C. At ambient temperatures >30°C mousedeer became hyper thermic, at ambient temperatures below their thermoneutral zone, mousedeer increased heat production by shivering; as a result, they were able to maintain their body temperature down to an air temperature of 15°C, but there was some evidence that at air temperatures < 15°C, they were unable to do so. Mousedeer have little subcutaneous fat (< 0.05%; Vidyadaran et al., 1983), their hair coat does not have the texture of a good insulating material and also their legs are extremely thin with poor insulation; thus, mousedeer do not appear to be able to affect a diminution in their thermal conductance at low air temperatures (Whittow et al., 1977).

Figure 13. At first glance, the coat of a mousedeer looks to provide good insulation but this is not the case. Photo courtesy of M. van Elderen.

A considerable increase in water loss occurred at temperatures >30°C (Whittow et al., 1977), but as observed in another study, transfer of animals from 26°C to a temperature above their thermoneutral zone (33°C) did not significantly increase their water turnover (Kamis et al., 1994). It can be concluded, that the thermoneutral zone of mousedeer is quite narrow, that their mechanisms of temperature regulation are relatively ineffective, and that mousedeer are not particularly well adapted to heat or cold; this conclusion conforms with mousedeer behavior, their geographical distribution and habitat's nature (Whittow et al., 1977).

[3] experimental animals were given long bean, kangkong (*Ipomoea reptans*), orange, raw peanuts, rabbit pellets.

[4] experimental animals were given only fresh Lundai (*Sapium baccatum*) foliage.

Respiratory Frequency & Oxygen Consumption

The respiratory frequency of mousedeer is quite variable, and related to a number of factors, such as e.g., restlessness, shivering or rumination. It increases as well at lower ambient temperatures, as a result of shivering, as at higher temperatures (Whittow et al., 1977). Above 34°C, Whittow et al. (1977) observed polypnea and open-mouth panting. Oxygen consumption was minimal at air temperatures between 26.6 and 29°C (0.539 ml O2/ g/ h; in heat units and related to body weight 70.2 kcal/ day/ kg 0.75). The oxygen consumption was minimal (mean, 0.539ml O_2/g/hr.) at air terraces between 26.6 and 29.O"C (Whittow et al., 1977).

Thyroid Activity

Thyroid activity in captive lesser mousedeer was assessed by Kamis (1980); briefly, at 27°C ambient temperature, plasma levels of T3 und T4 were 0.47 1 0.06 ng/ml and 36.21 1 2.3 ng/ml. Exposure to heat caused the animals to suppress their metabolic activity; at 33°C plasma levels decreased to 0.28 1 0.04 ng/ml (T3) and 28.33 1 2.56 ng/ml (T4).

Hematological Characteristics

Erythrocytes of lesser mousedeer are known to be the smallest among mammals (Gulliver, 1870, 1875; Duke, 1963; Vidyadaran et al., 1979; Fukuta et al., 1996, 2007); diameters range from less than 1.5 up to 2.3 αm (eventually depending on the technique of preparation), the mean corpuscular volume ranges from 11 – 13.1 fl (unpublished data). In comparison, among domestic animals, goats are known to have the smallest erythrocytes with a mean volume of less than 25 to 31 fl (Kraft, 1999).

Fukuta et al. (1996, 2007) revealed by electron microscopy that erythrocytes of mousedeer varied in shape, including discoid, biconcave discs, flat oval, spheroidal, ellipsoid, and rod, triangular or irregular and intermediate forms; discs or biconcave discs were dominant. Mature erythrocytes from peripheral blood were nonnucleated and displayed a homogenous eosinophilic content, except for a central pallor due to biconcavity. Many erythrocytes showed one, rarely two or more, unique pits on their outer surface. Examining peripheral blood from more than twenty individuals of both sexes, the incidence of erythrocytes having such a pit varied individually from 2.3 to 47%. Within mature erythrocytes a complex vacuole-like structure was observed in the cytoplasm, which communicated with the extracellular space via a small perforation.

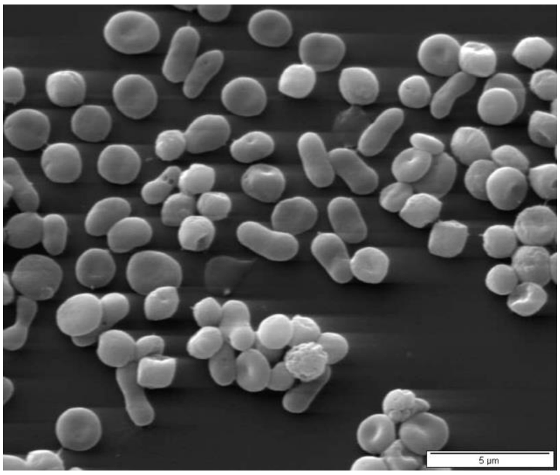


Figure 14. Electron micrograph of erythrocytes of a lesser mousedeer; bar=5 αm, photo courtesy by Dr. G. Wibbelt, Leibniz Institute for Zoo and Wildlife Research, Berlin.

In reticulocytes and erythrocytes of the bone marrow, in contrast, the incidence of these pits was less than 2% and communication of vacuoles with the extracellular space was hardly observed. This abnormal feature in the erythrocyte lineage is peculiar to the lesser mousedeer and not found in any other tropical ruminant. The nature or physiological meaning of these pits and vacuoles is unclear, but their appearance in immature erythroid cells suggests that they are congenital structures.

In view of the erythrocytes small size, haemodynamics of mousedeer have been studied in few animals by Snyder and Weathers in 1977. Briefly, the relative viscosity of mousedeer plasma was 1.97, 50% haemolysis occurred in 0.7% sodium chloride and the P50 of blood at pH 7.4 was 34 Torr (Snyder and Weathers, 1977); the average heart rate was 182 beats/min, the cardiac output ascertained as 145 ml kg–1 min–1, the mean arterial pressure as 99 Torr and the total peripheral resistance as 4.9 x 10 5 dyn s cm-5 (Weathers and Snyder, 1977).

Results of blood counts as provided by various sources are presented in chapter 2.6. Information on the reproductive physiology of lesser mousedeer is summarized in chapter 1.7.

1.4. Longevity

No information is available about the lifespan of free-living lesser mousedeer. In captivity life expectancies reported vary from 11 up to 16 years (Robin, 1988; Jones, 1993; Carey and Judge, 2000; Karasov, 2003). ZIMS for Studbook data revealed that the longest living breeding male was 14,07 years and the longest living breeding female was 14,04 years of age (ZIMS, 2023).

1.5. Ecology, Distribution & Conservation

Distribution

Members of the family Tragulidae are regarded as living fossils, the most ancient living representatives of early ruminants. Today's chevrotains are descendants of early Tragulids, such as *Archaeotragulus krabiensis*, that appeared in the Eocene; most probably, the first fossil tragulid was *Dorcatherium* from the early Miocene of Africa and Eurasia. Tragulids had a moderate radiation in the present-day subtropical and temperate latitudes during the middle Miocene but following climatic and vegetational changes in the northern hemisphere of the Old World in the late Miocene, they became restricted to more equatorial regions. Other members of the present infraorder Tragulina, the hypertragulids and leptomerycids survived in the North American region until the late Miocene. The first fossil record of the living genera of tragulids derives from the Pleistocene. Whereas *Hyemoschus* is said to be very similar to *Dorcatherium*, *Tragulus* appears to be somewhat more specialized from the traguloid lineage in aspects of both morphology and behavior (Janis, 1984; Karasov, 2003).
A complete estimate of the phylogenetic relationships among 197 species of extant and recently extinct ruminants, combining morphological, ethological, and molecular information can be found at Hernández Fernández and Vrba (2005).

Nowadays the Water Chevrotain *H. aquaticus* is found in west and central Africa (disjointed distribution from Sierra Leone to western Uganda), whereas *Tragulus* and *Moschiola* spp. inhabit south-central and south-east Asia (Nowak, 1999; Karasov 2003). Modern-day mousedeer, occur throughout Malaysia (Peninsula Malaysia, Borneo, and nearby islands), Indonesia (Java, Borneo and Sumatra and smaller islands), Singapore, Thailand, Cambodia, Laos, Vietnam, and southwestern China (Grubb, 2005). Nowak (1999) cites the former occurrence of mousedeer throughout Bangladesh, where it is said to be extirpated by human hunting. *M. meminna* can be found in southern India, Sri Lanka and, eventually, Nepal (the occurrence of *M. meminna* in Nepal is doubted) (Grubb, 2005).

Habitat

Lesser mousedeer inhabit the dense undergrowth of primary and secondary lowland forests but are occasionally found up to an altitude of 1100 m above sea level. They often reside among rocks, in hollow trees and thick bushes, preferably in areas near water, or traverse tiny tunnel-like jungle trails (Ahmad, 1994; Karasov, 2003; Farida, 2006).

Tragulus species remain in one vegetation type and in one home range throughout the year. However, no signs of competition were apparent during studies dealing with the coexistence of mousedeer species; referring to food size, circadian rhythm, and habitat preference they rather follow different ecological niches (Nordin 1978; Ahmad, 1994; Matsubayashi and Sukor, 2005).

From ecological characteristics and distribution ranges, Meijaard and Sheil (2008) suggest that the lesser mousedeer is an ecologically more adaptable species than the greater mousedeer, with the former species also occurring in drier, more open forests while the latter remains restricted to the wet tropics.

In beginning of the 1990s, densities of lesser mousedeer in Malaysian Borneo ranged between 21 and 39 animals/km2 le those of the greater mousedeer ranged between 37 and 72 animals/km2 (Heydon and Bulloh, 1997); but tropical rainforests are rapidly disappearing as land is cleared for e.g., timber, agriculture and development (Meijaard and Sheil, 2008).

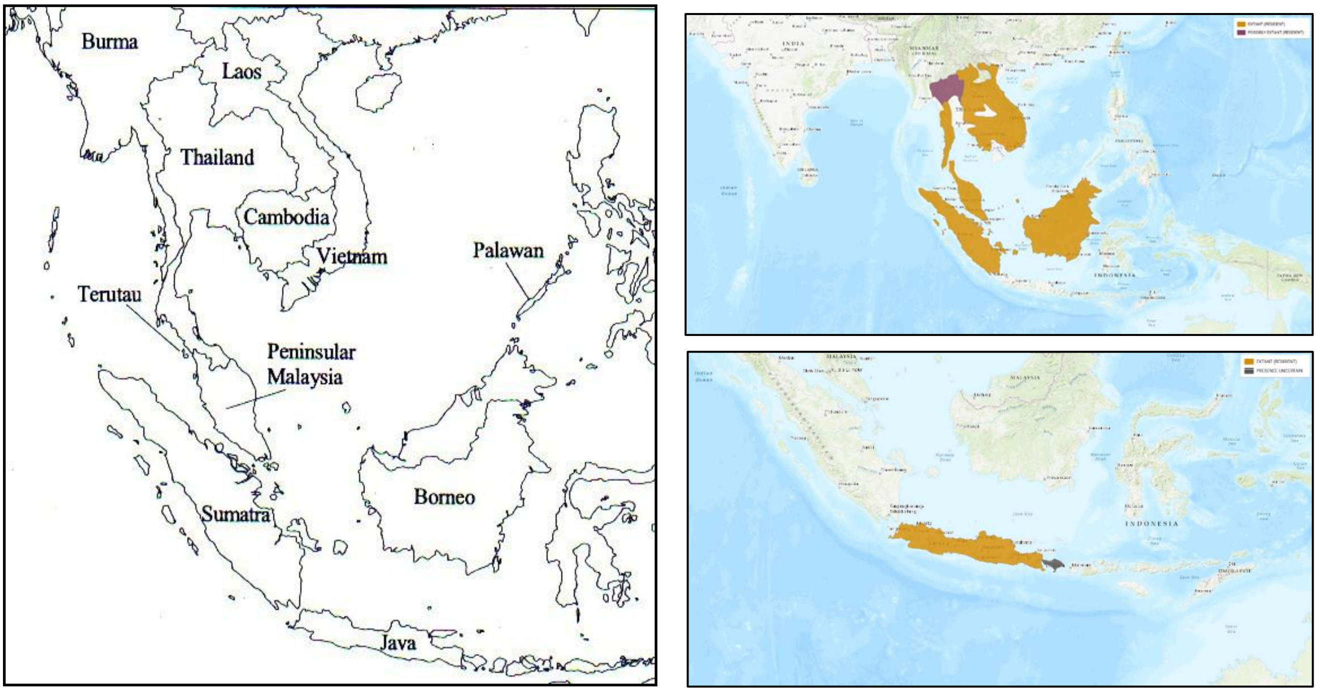


Figure 15. Geographic distribution of *Tragulus* spp. (Left) (Meijaard and Groves, 2004, modified), *Tragulus kanchil* (Top right) and *Tragulus javanicus* (Bottom right) (Duckworth et al., 2015, modified).

Threats

Multiple studies have been conducted investigating the impact of logging on wildlife. Results regarding mousedeer are controversial; whereas some researchers observed a remarkable adaptability to changing conditions (e.g., Johns, 1997; Laidlaw, 2000; Matsubayashi et al., 2003; Matsubayashi and Sukor, 2005), others noted a severe decrease of *Tragulus* densities in logged forests (Heydon and Bulloh, 1997; Davies et al., 2001). Meijaard and Sheil (2008) state that frugivorous ungulates such as the *Tragulus* sp. are negatively affected by post-logging conditions.

Due to a relatively high muscle-bone-ratio and dressing percentage, mousedeer represent a valuable source for meat production (Vidyadaran et al., 1983); traditionally, indigenous people have used meat and skin for self-sufficiency. Thus, it is not surprising that nowadays mousedeer still get hunted in all parts of their range (Lim, 1973; Kamis, 1994; Jinaka, 1995; Nowak, 1999; Karasov 2003; Meijaard et al., 2005; Duckworth et al., 2015). Another threat is that the animals are being captured and traded for the pet industry (Duckworth et al., 2015).

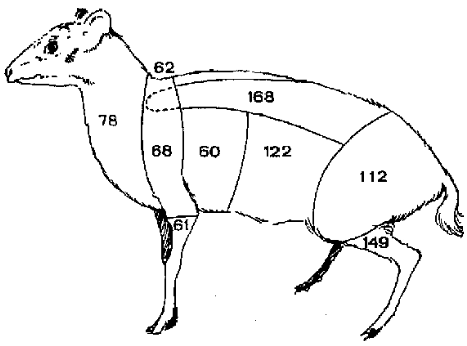


Figure 16. Muscle weight distribution of mousedeer relative to cattle (Vidyadaran et al., 1983, modified).

Importance for Humans

The lesser mousedeer is one of the world's smallest ungulates - following Huffman (2007) *T. javanicus / kanchil* and the African royal antelope, *Neotragus pygmaeus* are vying for the title of 'smallest ungulate'. Anyhow, symbolizing wit and keenness of mind, the mousedeer Sang Kanchil (or Kancil) is one of the most popular animal characters in Malayan folk stories and regarded as counterpart of wily animals like the red fox in European tradition (Mohd, 1976). Their readiness to be tamed, their quietness, and small size make them an attractive companion animal, foster-nursed mousedeer have been toilet trained like cats or dogs (Kudo et al., 1997, Nowak, 1999). Richardson et al. (1988) call lesser mousedeer 'semi-domesticated'. Several authors have supported the mousedeer's potential as laboratory animal for ruminant and medical studies (e.g., Fukuta, 1991; National Research Council, 1991; Kudo et al., 1997); as well in Southeast-Asian countries as in the United States colonies of lesser mousedeer are established.

Conservation Status

The International Union for Conservation of Nature (IUCN) classifies the majority of *Tragulus* and *Moschiola* spp. as being at 'lower risk' of extinction as most species are classified as Least Concern by the IUCN, only the Balabac chevrotain (*T. nigricans*), has been listed as Endangered by the IUCN in 2014 (Widmann, 2015). Two European Zoos introduced *T. nigricans* to their collection and already achieved first reproductive successes. Three *Tragulus* species (*T.javanicus, T. williamsoni, T. versicolor)* are classified by the IUCN as data deficient (Duckworth et al., 2015). Population trends of *Tragulus* and *Moschiola* species are unknown and require an update of data (*T. javanicus*, *T. kanchil*, *M. indica*, *M. kathygre*, *M. memmina*) or are classified as decreasing (*T. nigricans*, *T. napu*, *T. versicolor*, *T.williamsoni*) (IUCN 2023).

Conservation Actions

Distribution, status and conservation of Asian mousedeer were one of the topics during the EAZA Deer TAG meeting of 2005 in Bristol/ Bath; W.L.R. Oliver from the Philippines Biodiversity Conservation Programme presented various facts and formulated suggestions for future research and conservation priorities, which included (1) more detailed distribution/status surveys, (2) development of a properly structured, collaborative captive-breeding program, and (3) promotion of the species' flagship potential as a vehicle for the development of a meaningful biodiversity conservation program in the region (EAZA Annual Reports, 2005).

During the Deer TAG Regional Collection Plan 2019 meeting, conservation roles were defined for the EEP. Two out of the three roles will be indirect. The EAZA population will support ex situ conservation activities for the Balabac mousedeer (*T. nigricans*) and/ or the Silver backed mousedeer (*T. versicolor*) through fundraising. Secondly, by collecting and gathering information about the husbandry of mousedeer to develop their husbandry standards through for example the Best Practice Guidelines. And lastly the EEP has a general education role by keeping this species in the collection (Werner et al., 2019).

In the EEP Long Term Management Plan of 2023 for this species, the goals are to increase the population and to develop a population that is demographically stable to maximize the breeding population, to import unrelated animals for a healthy population and producing Best Practice Guidelines for the further development of the species husbandry. These goals will be achieved by reproductive planning and management strategy, improving husbandry knowledge and genetic research (ter Meulen et al., 2023).

1.6. Diet and Feeding Behavior

Food Preference

Based on feeding patterns and the morphology and physiology of their gastrointestinal tract as described in chapters 1.2 and 1.3, it was concluded that mousedeer tend to be ‘frugivorous ungulates’ (Heydon and Bulloh, 1997), ‘selective feeders’ (Medway, 1983; Nolan et al., 1995; Karasov, 2003; Farida et al., 2006), ‘browsers’ (Kay et al., 1979; Endo et al., 2002), ‘highly selective browsers’ (Janis, 1984) or ‘concentrate selectors’ (Kay et al., 1979; Hofmann, 1988; Vidyadaran et al., 1994; Agungpriyono et al., 1992, 1995).
In the wild, mousedeer are reported to favor young, easy to digest leaves with soft and palatable trunks and low levels of secondary metabolites, flowers and trunks of trees, shrubs and grasses, herbs, lichens, shoots, vegetables, forbs, fallen fruits and berries, seeds and buds; only in captivity they have been observed eating arthopods (Hoogerwerf, 1970; Vidyadaran, 1982; Medway, 1983; Janis, 1984; Robin 1988; Nowak, 1999; Matsubayashi et al., 2003; Karasov, 2003; Farida et al., 2006). Lundai foliage (*Sapium baccatum*), a tropical shrub, is said to be an important component of a mousedeer’s diet in its natural habitat (Kudo et al., 1995; Nolan et al., 1995).

A recent study on habitat distribution and diversity of plants serving as food resources for mousedeer in the Gunung Halimun National Park, West Java, Indonesia, lists >40 plant species of which mainly leaves, and young trunks are consumed (Farida et al., 2006) (table 7). The nutrient analysis of feed plants selected by mousedeer on West Java showed considerable variation: ash (mineral) content ranged from 5.2 to 32.9% (average 9.17% +/-1.8), protein from 10.3 to 34.4% (average 19.9% +/- 5.8), fat from 0.7 to 2.9% (average 0.9% +/- 0.3), rough fiber from 9.6 to 46.3% (average 26.4% +/- 9.9) and energy from 2576 cal/g to 4691 cal/g (average 3493.5 cal/g +/- 456.2).
Information on fruits eaten by *Tragulus* spp. is provided by a study on the impact of logging in the Ulu Segama Forest Reserve in Sabah, Malaysian Borneo, (Heydon and Bulloh, 1997) (table 8). Matsubayashi et al. (2003) reported the intake of fallen green leaves of a pioneer tree species (*Octomeles sumatorana*), of fruits of a tall Ficus-tree and of a whitish mushroom (*Russula* ssp.). A free-living mousedeer was temporarily held in captivity; it consumed various leaves and fruits of local plants (*Ficus spp.*, *Dillenia borneensis*, *Macaranga hypoleuca*, *Ipomoea aquatica*, *Poikilospermum spp.*), as well as common vegetables (sweet potato, long bean, and carrot). Stomach contents of two free-ranging individuals found dead contained large amounts of green leaves, brown-colored dead leaves and a small, unspecified fruit (Matsubayashi et al., 2003).

Table 7. List of feed plants selected by mousedeer (*Tragulus javanicus*) in Gunung Halimun National Park, West Java, Indonesia (Farida et al., 2006, modified).

Family	Scientific Name	Parts Consumed	Kind of Plant
Acanthaceae	*Tetraglochidium bibracteatum*	leaf & young trunk leaf	climbing
Amaranthaceae	-	& young trunk, flower	shrub
Araceae	*Schismaglottis calyptrata*	young trunk	shrub
	Schismaglottis rupestris	young trunk	shrub
Asteraceae	*Adenostemma macrophyllum*	leaf & young trunk	shrub
	Bidens chinensis	leaf & young trunk	shrub
	Clibadium surinamense	leaf, flower & fruit	shrub
	Erechtites valerianifolia	leaf & young trunk	shrub
	Galinsogo parviflora	leaf & young trunk	shrub
	Mikania cordata	leaf & young trunk	climbing
Balsaminaceae	*Impatiens javensis*	leaf & young trunk	shrub
Caryophyllaceae	*Drymaria cordata*	leaf & young trunk	shrub
Commelinaceae	*Commelina paleata*	leaf & young trunk	shrub
Convolvulaceae	*Ipomoea batatas*	leaf & young trunk	climbing
Cucurbitaceae	*Cucumis sativus*	young leaf	climbing
	Cucurbita moschata	young leaf	climbing
	Sechium edule	young leaf	shrub
Cyperaceae	*Carex baccans*	young leaf	shrub
Euphorbiaceae	*Omalanthusgiganteus*	leaf & young trunk	shrub
Fabaceae	*Teramnus labialis*	leaf & young trunk	climbing
Onagraceae	*Jussieua linifolia*	leaf & young trunk	shrub
Poaceae	*Axonopus compressus*	leaf & young trunk	grass
	Digitaria sp.	leaf & young trunk	grass
	Eleusine indica	leaf & young trunk	grass
	Isachne sp.	leaf & young trunk	grass
	I. albens Lophaterum	leaf & young trunk	grass
	gracile Miscanthus	leaf & young trunk	grass
	floridulus Panicum	leaf & young trunk	grass
	trigonum	leaf & young trunk	grass
	P. repens	leaf & young trunk	grass
	Paspalum conyugatum	young leaf	grass
	Setaria barbata	leaf & young trunk	grass
	S. palmifolia Urochla	leaf & young trunk	grass
	muticum Plantago	leaf & young trunk	grass
Plantaginaceae	*major Polygala*	leaf, flower & young trunk	shrub
Polygalaceae	*paniculata*	leaf & young trunk	shrub
Polygonaceae	*Polygonum chinensis*	leaf & young trunk	shrub

Continuation table 7.

Family	Scientific Name	Parts Consumed	Kind of Plant
Rubiaceae	*Anotis hirsuta*	leaf & young trunk	shrub
	Boreria alata	leaf, flower & young trunk	shrub
	Hedyotis auricularia	leaf & young trunk	shrub
	Mussaenda frondosa	young leaf	climbing
Thelypteridaceae	*Macrothelypteris torresiana*	leaf & young trunk	herb
Urticaceae	*Elatostema sp.*	leaf & young trunk	shrub
Verbenaceae	*Stachytarpheta jamaicensis*	leaf & young trunk	shrub

Table 8. List of plant species whose fruits were selected by *Tragulus* spp. in the Ulu Segama Forest Reserve in Sabah, Malaysian Borneo (Heydon & Bulloh, 1997, modified).

Family	Genus	Species	Fruit Type	*Tragulus* species		
				T. javanicus	*T. napu*	*unknown*
Annonaceae	*Polyalthia*	*sumatrana*	berry	+	+	
Ebenaceae	*Diospyros*	*macrophylla*	berry		+	
Euphorbiaceae	*Aporusa*	species	capsule	+		
	Endospernum	*peltatum*	drupe			+
Fagaceae	*Quercus* *Garcinia*	species	nut		+	
Guttiferae		*forbesii*	berry		+	
	Litsea	*parviflora*	berry			+
Lauraceae		*caulocarpa*	berry	+		
	Notaphoebe	*orocola*	berry			+
	Dialum	species *indum*	berry		+	
Leguminosae	*Strychnos* *Aglaia*	*L.* species	nut		+	+
Loganaceae	*Chisocheton*	species	berry		+	
Meliaceae	*Dysoxylum*	species	berry		+	
	Lansium	species	capsule		+	
	Artocarpus *Ficus*	species *dadah*	capsule	+		
	Dimocarpus	species	berry		+	
Moraceae		*longan*	syncarpic form		+	
	Paranephelium	*malesiana*	syncarpic form	+	+	
Sapindaceae	*Microcos*	*xestophyllum*	berry		+	+
		antidesmifolia	capsule	+		
Tiliaceae			drupe		+	+

Feeding Behavior

Lesser mousedeer display a characteristic behavior of small forest ungulate cautiously wandering around. Foraging is accompanied by brisk movements with the snout lowered to explore the forest floor, moving is stopped while chewing with the head kept well up (Barrette, 1987; Ahmad, 1994; Kamis et al., 1994). Traditionally, the forest-dwelling lesser mousedeer were thought to be nocturnal (Barrette, 1987; Kamis et al., 1994; Nowak, 1999; Karasov, 2003) and maybe due to this only few studies report on the feeding behavior in their natural habitat. However, recently gained results on activity and habitat use on Borneo and the Malay Peninsula, indicate that Lesser Mousedeer have a diurnal or crepuscular pattern of behavior and provide a small insight into the foraging behavior of this cryptic species (Ahmad, 1994; Miura et al., 1997; Matsubayashi et al., 2003; Matsubayashi and Sukor, 2005).

Ahmad (1994) although qualifying that it was a rare event to see mousedeer feeding, observed on several occasions that mousedeer benefited from the activity of arboreal folivores and frugivores species, such as birds, bats, or small mammals, in taking what the latter let drop. Such mutual interaction is not unusual at all, but the idea of a vast buffet for mousedeer is shattered, when looking at the results from Miura et al. (1997). Miura and colleagues examined frugivory of vertebrates in a forest reserve on the Malay Peninsula by using automatic camera systems, which they placed under more than 70 different tree species. As major consumers of fallen fruits were identified: pig-tailed macaque, long-tailed porcupine, long-tailed giant rat, three-striped ground squirrel, red spiny rat, banded leaf monkey and the common porcupine, which accounted for ~89% of 2554 pictures of mammals; the lesser mousedeer followed on place nine of the 'visitor ranking' and was thus not considered as a major consumer of fallen fruits.

1.7. Reproduction

Sexual Maturity, Sexual Behavior & Seasonality

Lesser mousedeer reach sexual maturity at three to five months of age, adult size at five months. However, the prominent canines of young males do not extend beyond the upper lip until the animals are about nine to ten months old (Kamis et al., 1994; Kudo et al., 1997).

Earliest age of copulation of male mousedeer was seen at 166 days, earliest age of conception and first parturition of females at 125 resp. 258 days of age (Kudo et al., 1997). From behavioral observations on captive individuals, it was concluded that lesser mousedeer are (serially) monogamous resp. that they have a tendency to form pair bonds (Robin, 1988; Kamis et al., 1994; Nowak, 1999; Karasov, 2003); from field studies Matsubayashi et al. (2006) suggest a facultative monogamous or polygynous mating system.

Figure 17. Breeding couple during copulation at ARTIS Amsterdam Royal Zoo, photo courtesy of R. van Weeren.

A seasonality for sexual behavior has neither been described from the wild nor from captivity; however, mating behavior as well as parturitions are observed throughout the year (Kamis et al., 1994; Kudo et al., 1997). The sexual cycle of females in captivity is estimated to be 14-16 days, the duration of the mating period lasts about one or two days where copulation occurs several times (Robin, 1979; Kudo et al., 1997).
Sexual behavior includes the male 'testing' the female for receptivity by sniffing the vulva, rhythmical vocalizations and pressing the dorso-lumbal region with its chin, where the intermandibular gland is located (Cadigan, 1972; Janis, 1984; Kamis et al., 1994; Kudo, 1997; Karasov, 2003). Robin (1979) also describes the reciproqual testing of urine, suckling and 'flehmen' by the male (the latter is denied by Janis, 1984) and elements of aggressiveness as part of courtship behavior. Cadigan (1972) and Robin (1979) published quite detailed reports about their observations of copulatory behavior.

Displays of receptiveness and refusal were summarized as follows; if receptive, the female extends the rear legs so that its hind-quarters are far higher than its shoulders, it arches its back slightly upward and stands still; if not receptive, the female flexes her rear legs until it is almost touching the ground thus putting the rear end at a level below its shoulders, arches its back slightly downward and moves rapidly away. Copulation lasts from a couple of seconds up to several (in average 4) minutes and usually a series of short copulations is followed by a longer one; with respect to the coiled penis of male mousedeer this behavior was put down to the difficulty of intromission as is the case in suids (Robin, 1979). Following Robin (1988) males prefer primi- or multiparous to nulliparous females.

Figure 18. Offspring just after parturition and dam, ARTIS Amsterdam Royal Zoo, photo courtesy of R. van Weeren.

Gestation

Reports on gestation length of the lesser mousedeer differ considerably: 140 to 177 days is noted by Kamis et al. (1994) and Karasov (2003), and 139 to 141 days by Robin (1979, 1988). Judging from the intervals of continuous parturitions in their laboratory colony, Kudo and his colleagues (1997) observed gestations between 136 to 164 days in length but estimated an actual gestation period of 134 +/- 2 days. Whereas Kudo et al. (1997) assumes that a delayed implantation of the fertilized egg may occur due to lactation, Robin (1979) notes the possibility of superfetation.

Following Kudo et al. (1997) pregnancy is not noticeable, but it was observed that pregnant females in the laboratory colony tended to sit all the time a few days before parturition. Interestingly respondents of the survey of 2007 listed signs, which are regarded as indicative for pregnancy (please see chapter 2.4).

A small insight into the intrauterine development of a mousedeer-fetus is given by Kimura at al. (2004); eruption of incisors, hair growth and coloration of hoof and muzzle were first observed at 60.5 mm hind foot length.

Partus

Following Cadigan (1972) parturition has never been observed during daylight, Kudo and colleagues (1997) observed most parturitions in early morning hours between 6 to 10 a.m. During labor the female may emit frequent 'chirping' and occasionally slight squeals. Youngs usually appear in dorsal sacral position and anterior presentation with one or both front legs extended along the rump. After birth the dam removes and eats the neonate membranes, and the infant may be on its feet within 30 minutes. Litter size is usually one, twinning is rare (Cadigan, 1972; Robin 1979; Kamis et al., 1994; Kudo et al., 1997). In proportion to the body mass of adult lesser mousedeer, the weight at birth of offspring is usually relatively large, ranging from 120 to 250 g (Kudo et al., 1997; Robin, 1988).

Lesser Mousedeer are reported to have a post-partum estrus. Mating occurs within 24-48 hours after birth of the young, but copulation was also observed as soon as 30 minutes after birth; as a result, mousedeer are capable of almost continuous pregnancy through most of their adult lives (Robin, 1988; Kamis et al., 1994; Kudo et al., 1997; Karasov, 2003; Kimura et al., 2004).

Development & Mother-Calf Relationship

Although young are precocial, they remain hidden for the first days, while the dam stays away except for short suckling periods. Both communicate by high frequency sounds of chirping. Dams nurse their young in a standing position, raising their hind leg. In between observing their surroundings, they carefully lick the young's head, back and their own udder. Each sucking lasts from three to six minutes. Subsequent grooming and care of the infants anogenital region are important elements of the mother-calf relationship (Robin, 1979), and have been observed being taken over by other adult females (Cadigan, 1972). At about seven days of age, young start following their mothers and latest at the end of their second week they start consuming solid food (Robin, 1979). Young are weaned at about three months (10-13 weeks) and disperse from the mother's home range when they reach sexual maturity (Robin, 1979; Kamis et al., 1994; Karasov, 2003). A short report on the reproductive behavior of the greater mousedeer, *T. napu*, was published by Davis in the International Zoo Yearbook in 1965. The original article mistakenly identified the species as *T. javanicus*, but in the 1967 Yearbook a corrigendum re-identified it as *T. napu* (Dekker and Schmidt ,1987).

1.8. Behavior

Activity

As lesser mousedeer are almost never in the open, and due to their cryptic nature, seldom seen in the forest, most writers have concluded and/ or cited that mousedeer are nocturnal (Barrette, 1987; Kamis et al., 1994; Nowak, 1999; Karasov, 2003). Hoogerwerf (1970) qualified:" Although the kanchil is also active at night, as could be regularly established in Udjong Kulon and was also noted by other observers both in nature and in captivity, the species is not an expressly nocturnal animal". This opinion could be confirmed by numerous studies during the last decades; results from Robin (1979), Ahmad (1994), Miura et al. (1997) and Matsubayashi et al. (2003, 2005) suggest that mousedeer are active irrespective from day or night with a predominant crepuscular pattern of activity.

Robin (1979) investigated numerous behavioral objectives in a captive population at Zürich Zoo and defined their activity pattern as 'poly-phasic', peaking between 7.00 till 9.00, 12.00 till 14.00 and 16.00 till 21.00 h.

Ahmad (1994) studied several behavioral and ecological aspects in a Bornean rain forest by radiotracking; he found mousedeer activity being distributed throughout day and night, peaking during dawn and dusk. The normal pattern was a frequent alternation of activity and resting, each status usually lasting less than two hours. Being ruminants the length of active and inactive periods determining the daily activity of mousedeer are closely related to internal factors like foraging and digestion; including observations on captive individuals, Ahmad suggests that short lasting activities and rests coincide with availability of food in their natural habitat and usually short rumination times respectively, whereas irregularity in lengths may be the result of influence by external factors such as weather, social partners and habitat structure.
Miura et al. (1997) examined frugivory of vertebrates in a forest reserve on the Malay Peninsula by using automatic camera systems; judging from the visiting times printed automatically in the pictures, it became evident that mousedeer were looking for food irrespective of day or night, but with a majority of visits around 18.00 h.

Matsubayashi et al. (2003, 2005) followed mousedeer by radiotracking and camera trapping; active mousedeer wandering or foraging on forest floor were observed only during light periods and no or only few active behaviors were observed during dark periods. In contrast, resting individuals were mostly observed during dark periods. Within their home ranges the mean daily distances travelled were about 500 m/day, and not significantly differing between sexes or from dry to rainy season. Distances moved per hour were 21.9 +/- 19.3 m, showing two clear peaks; in both sexes, the longest distances moved per hour were observed during early morning (5.00–7.00 h) and late afternoon (15.00-17.00 h), the shortest distances moved per hour were observed around midday (11.00–13.00 h) and midnight (23.00–1.00 h).

Locomotion

Lesser mousedeer move around with the wariness and stealth characteristic of small forest mammals. Foraging is accompanied by brisk movements with the nose lowered to sniff. Mousedeer stand with their back slightly arched and the rump curved downwards (Kamis et al., 1994) and as is the case with multiple behavioral and morphological features, also locomotion shows some primitive patterns: diagonal walk, a rather primitive way of gallop and a dorsomobile column (Heckner, 1982). Studies on muscle distribution and functional strategies of the hindlimb confirmed observations of enormous agility, but rather low speed and stamina in this species (Vidyadaran et al., 1983; Endo et al., 2006). A comparison of standard muscle groups showed relatively more muscles in hindlimb, around the spinal column and in the abdominal wall than in other parts of the body (Vidyadaran et al., 1983).

When alarmed or nervous, mousedeer stand still and raise one front leg, or they curve the back and sink down on their hind legs. They may rapidly beat their hooves on the ground at speeds of up to seven times per second, creating a 'drum roll'. When surprised or threatened, mousedeer make an impressive leap into the vegetation or take up a somewhat 'freezing' attitude, by pressing themselves down against the ground. It is reported that mousedeer are equally excellent swimmers and divers (Hoogerwerf, 1970; Robin, 1988). To rest, they sit on their hind legs or crouch in the understory. Unlike larger ungulates, mousedeer first lower their hind quarters when laying down; subsequently forelegs are bent and tucked under (Kudo et al., 1997).

Social Behavior

Generally, mousedeer are referred to as solitary animals. As pointed out by Barrette (1987), the word 'solitary' refers to sightings and does not include other means of communication, such as e.g. scent marking, and thus, 'solitary' should not be taken as a synonym for 'asocial' or lack of social association. During field studies on peninsula Malaysia and Borneo 70-95% of individuals were seen singly, less than 30% in groups of two and maximum 5% in groups of three individuals (Ahmad, 1994; Miura and Idris, 1999; Matsubayashi et al., 2006). In small forest ungulates, 'groups' are usually courting pairs, rarely mother and offspring, or a male accompanying the latter group (Barrette, 1987). Miura and Idris (1999) observed animals of a mousedeer 'group' synchronizing their activities like eating, walking, or moving while maintaining continuous inter-visibility.

Through full day radiotracking, Matsubayashi et al. (2006) measured mean distances between individuals; paired individuals were on average as close as ~10 m, while non-paired individuals kept a distance of on average ~64 m. Home range sizes ascertained in different study areas measured ~6 ha in males and ~4 ha in females, without any significant difference between sexes (Ahmad, 1994; Matsubayashi et al., 2006); however, Ahmad (1994) found a positive correlation between body and home range size. Mousedeer are philopatric, sedentary animals; their home ranges are not subject to large scale movements, although they may vary in shape and size. Information about differences in gender are contrasting; whereas Matsubayashi and colleagues found male home ranges being more temporary, Ahmad found females to be less sedentary. From direct observation of a single female establishing a new home range prior to parturition, he concluded that this behavior may play a role in the process of dispersal of young. Daily usage of home range areas varied between 15 and 30% (Ahmad, 1994).

Overlapping of home ranges and core areas was shown in both studies, but core areas were more separate among same sex individuals and overlapped more among opposite-sex individuals. Based on these extents of overlapping of home ranges and observations on free-ranging mousedeer, Matsubayashi et al. (2006) suggested that the social system of mousedeer is facultative monogamous or polygynous.

In contrast to the general opinion that male mousedeer are territorial (e.g. Nowak, 1999; Karasov, 2003), Ahmad (1994) stated that overlapping of home ranges suggests that mousedeer are not territorial. He further argues that home ranges are not exclusive, that no boundary patrolling was observed and that the occurrence of fights among conspecifics in their natural habitat is low; however, both genders of mousedeer are intolerant of same-sex individuals and generally, activities and movements are directed towards avoidance of contact and competition.

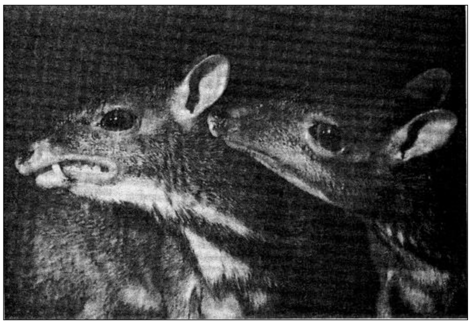


Figure 19. Facial expression of an agitated mousedeer (Robin, 1979).

As noted by Vidyadaran et al. (1981), canines in males may serve more as weapons of display rather than for engaging in serious fighting. Fighting between female mousedeer is generally rare. Scent marking with secretions from intermandibular, anal or preputial glands may be performed to show dominance and conspecific intolerance, thus ensuring individual spacing, but also to make mating possible (Robin, 1979, 1988; Ahmad, 1994). Still, Davison (1980) published a detailed report on various postures, vocalizations and sequences observed during a fight between two male mousedeer; following Ahmad (1994) this description should be reconsidered since it implies an exclusiveness of territory as causal background which could not be confirmed during later field studies. However, Davison's speculation about fighting, being more pronounced on a seasonal basis along with highest fruit production should be kept in mind. Contacting other individuals is usually performed by sniffing at the head or in the flank, in the inguinal or anal region. When feeling annoyed, the contacted animal may lift the corners of its mouth, a unique behavior among ruminants, and turn its head to the side (Robin, 1979).

Elements of nervousness include drumming as described above or side to side chewing. Vocalizations are rare, and rather occur between dam and offspring, but mousedeer may flee squeaking loudly (Robin, 1979, Ahmad, 1994). Detailed descriptions of different behavioral elements can be found at Robin (1979), from his observations on captive lesser mousedeer at Zürich Zoo.

Living solitary, concealed, and practicing only basic social interactions are important factors to protect mousedeer from predation in their natural habitat (Ahmad, 1994); however, this behavior and the, compared to other ungulates, lack of social hierarchy are also regarded as evolutionary 'primitive' (Janis, 1984).

Predation

Mousedeer are preyed upon by a large number of carnivorous mammals, crocodiles, snakes, lizards and birds of prey (Ahmad, 1994; Kamis, 1994) For their meat and skin they are also widely sought-after by people (Lim, 1973; Kamis, 1994; Jinaka, 1995; Nowak, 1999; Karasov, 2003; Meijaard et al., 2005).

Section II Management in Zoos

In the following section different aspects of lesser chevrotain husbandry will be addressed and results of surveys among EAZA EEP participants in 2007, 2017 and 2023 as well as of a preliminary study on necropsy reports will be presented (All referred to below as 'unpublished data', ''date'').

2.1. Enclosure

In general, warm enclosures within small mammal houses have proven to be a suitable housing option for lesser chevrotains; latterly, this species is also more often kept in spacious tropical halls (Puschmann, 2004) and ''walkthrough exhibits'' (EEP survey, unpublished data, 2007). Four out of the fourteen (4/14) institutions are housing lesser chevrotains in walkthrough enclosures (EEP survey, unpublished data, 2023).

Dimensions

Since breeding pairs of lesser chevrotains established as laboratory animals reproduced successfully in cages of ~0.5 m^2 (Kudo et al. 1997), it seems as if the available space is not a primary requisite for successful reproduction. However, the home sizes range ascertained in the wild measures ~5 ha, and animals travel ~500 m daily, and that the mean distance during movement even between paired individuals was rarely less than ~10 m (Matsubayashi et al., 2003; 2006). Therefore, it might be assumed that too little space may lead to restlessness and stress.

It is recommended to house individuals in complex and foliage dense enclosures (Lemos de Figueiredo et al., 2021) to allow for maximum animal welfare, reproduction and educational efforts. However, a compromise needs to be found between spaciousness and a dimension which facilitates observation and management of individuals and groups.

Dimensions of indoor areas per breeding couple in European Zoos range from 15 up to 1800 m^2. Twelve out of the fourteen respondents are housing the animals indoors all year round.

The results of the 2017 and 2023 survey are consistent with the original survey from 2007. However there has been an increase in the institutions which house lesser chevrotains both indoors and outdoors (n=2) (EEP survey, unpublished data, 2017; 2023). One of these additional institutions is able to give their chevrotains access to the outdoor facility for 8 months. The other holder is housing the animals outdoors all year round, although this is only possible due to the regional climate characteristics (EEP survey, unpublished data, 2023). The outdoor enclosures dimensions range from 51 to 1353 m^2.

Furnishing and Maintenance

This species naturally occurs in dense forests, and it is therefore important to replicate this environment in lesser chevrotain enclosures. De Figueiredo et al. (2021) found that vegetation cover on ground level is an important aspect of enclosure furnishing for lesser chevrotains and positively affects breeding success, foraging and general activity in this species. It also serves as shelter and visual barriers for adult animals; permanent visual contact may induce agonistic behavior and increase stress. Pairs that were forced to be in close proximity to each other were less likely to breed successfully (de Figueiredo et al., 2021).
Furthermore, hiding possibilities are essential for newborns as offspring do not follow their mother but remain hidden in dense vegetation until about seven days of age (Robin, 1979). In the first European Studbook for the lesser chevrotain (Dekker and Schmidt ,1987), it was hypothesized that a high perinatal mortality in captive populations may also be due to insufficient hiding possibilities.
Items proven to be effective enclosure furniture include living shrubs and trees which form a dense understory of vegetation as well as dried tree trunks, logs, rocks, wooden boxes, and artificial items such as halved flower tubs (unpublished data, 2007). The number of hiding possibilities should exceed the number of animals per enclosure. It is also important that individuals have the option to conceal themselves from the public, either by the options mentioned above or by allowing the individual to choose to go behind the scenes.

Figure 20. Enclosure furniture at ARTIS Amsterdam Royal Zoo, photo courtesy of M. Dijkstra.

The majority of holders (n=11) provide multiple shelter areas per individual, 11 out of the 13 respondents provide logs for their chevrotains and 10 of the 13 respondents provide artificial shelter boxes for their chevrotains.
Vegetation plays a big role in enclosure furniture and should not be overlooked as it positively affects breeding success, foraging and activity in this species (de Figueiredo et al., 2021). Enclosure foliage may also serve as forage material, please see chapters 1.6 and 2.2. A list of plant species that are being used by current institutions can be found in appendix I; this list is formed by the EEP survey of 2023.
The questionnaire distributed in 2023 asked what kind of plant density the enclosure provided. The institutions were able to choose from low, medium, and high plant density. Out of the thirteen institutions, four institutions provide a high level of plant density in the enclosure (n=4). Medium density was listed by seven zoos (n=7). Only two zoos provided a low density of plants (n=2). Lastly one holder listed the plant density as low/medium (n=1) (EEP survey, unpublished data, 2023). Due to the fact that lesser chevrotain inhabits the undergrowth of primary and secondary forests, it is recommended to keep the species in densely planted enclosures (figure 21).

Enrichment options are correlated with the furniture and design of the enclosure. Ten out of the thirteen respondents are providing their lesser chevrotains with physical enrichment (n=10). Physical enrichment is provided daily at two institutions (n=2); this could be offering foraging materials such as leaves different substrates and providing novel objects. This type of enrichment is partly incorporated in the design of the enclosure. Five institutions are providing physical enrichment weekly (n=2). Four out of the thirteen holders are providing monthly physical enrichment (n=4) (EEP survey, unpublished data, 2023).

Figure 21. Details of mousedeer enclosures at Tierpark Dählhölzli, Bern (left, photo courtesy of Dr. M. Rosset), and Leipzig Zoo (former species holder) (right, photo courtesy of Prof. Dr. K. Eulenberger).

Shallow pools, ponds or rivers are a common feature in chevrotains enclosures. Nine out of the thirteen (n=9) institutions are providing a form of water in their enclosure (EEP survey, unpublished data, 2023). The presence of water-filled ponds promotes activity (i.e. foraging, moving) in captive lesser chevrotains, which shows that ponds may be an important enclosure feature for these animals (Lemos de Figueiredo et al., 2021). Nevertheless, it has to be noted that cases of newborns drowning have been reported. As a safety measurement, water basins should be emptied and filled up with bark or wood shavings when offspring is present (EEP survey, unpublished data, 2007).

Olfactory enrichment is provided to lesser chevrotains by various holders. The chevrotains that are living in a mixed exhibit are continuously stimulated by the smell of the other species, it is therefore presumed that all the institutions that keep lesser chevrotains in mixed-species enclosure provide olfactory enrichment. The other data gathered from the survey when looking at the frequency that olfactory enrichment is provided are weekly (n=1), rarely (n=5) and never (n=5). It can therefore be assumed that intentional olfactory enrichment is not often provided to this species, but we except that providing olfactory enrichment to this species could be beneficial.

It is important to note that the animals are not only getting stimulated by enrichment and interactions with other animals in the enclosure (if applicable), but also through interactions with zookeepers and visitors. Most of these interactions will happen during visitor hours. It is important to take these external factors into account when designing enclosures or when introducing new animals to their exhibits that are visible to the public (EEP survey, unpublished data, 2023).

Figure 22. Chevrotain in resting position directly at the window, ARTIS Amsterdam Royal Zoo, photo courtesy of M. Dijkstra.

Maintenance of the enclosure comprises of daily removal of food leftovers, and regular (depending on the enclosure size) removal of feces. Periodical maintenance is comprised of changing enrichment and refreshing substrate (depending on enrichment possibilities and type of substrate).

Substrate

The enclosure ground should allow secure footing and comfortable resting. A combination of bark chippings and humus, peat and/or leaves has proven to be suitable substrate for lesser chevrotains. Sandstone can be used in parts of the enclosure in order to prevent overgrowth of hooves. Loose sand as well as concrete should be avoided: several cases of sand intake, sedimentation within the digestive system and fatal obstipation and/or enteritis have been reported (EEP survey, unpublished data, 2007).

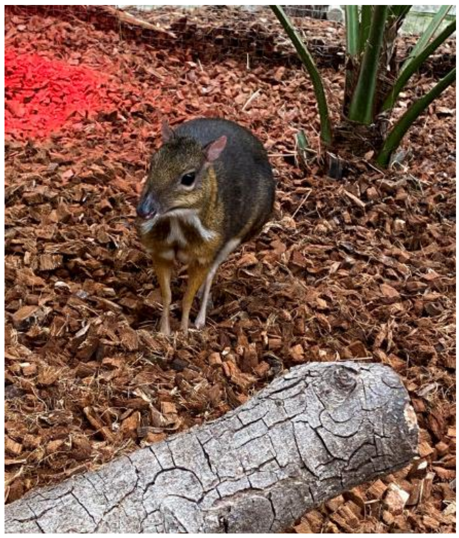


Figure 23. Chevrotain housed on coconut bark (Pairi Daiza, Cambron, 2023).

As already noted in the first edition of a chevrotain manual in 1987, a high incidence of injuries and inflammations (e.g., pododermatitis) of the hooves have been recorded in individuals, which were housed on a hard ground like concrete (Dekker and Schmidt, 1987). Attention should be paid when providing straw as a substrate since animals may get entangled with their tiny legs. In view of the request 'comfortable resting' the high incidence of hyperkeratotic areas in the sternal region, in some cases progressing to fatal decubitus-like lesions, appears noteworthy (unpublished data, 2007). These skin lesions may be avoidable by providing a soft substrate such as humus and/or leaves in the animals' resting places.

The 2023 survey asked current lesser chevrotain holders which kind of substrate they provide in their enclosures, 13 holders responded to this question. The most common substrate provided to chevrotains were bark (n=10), Leaves (n=9), other (n=7), humus (n=5), sand (n=4), peat (n=3) and straw (n=3). The "other" substrates are; normal soil (n=4), mulch (n=1), woodchips (n=1), coconut bark (n=1), pine bark (n=1), Hay (n=1), rocks (n=1), resin (n=1) and cement (n=1). Most holders provide multiple substrates in their enclosure (n=12) (unpublished data, 2023).

It should be noted that some types of substrates need to be changed/ refreshed more frequently than others. This depends on the contribution of the substrate to a bioactive underlayer. Substrates with these functions do not have to be refreshed as regularly as substrate types that are only used for hygienic purposes. The frequency of changing substrates was mentioned in the survey. Thirteen respondents answered this question, most holders changed their substrate annually (n=5), followed by never (n=3), monthly (n=2), when necessary (n=2), and daily (n=1) (unpublished data, 2023).

Environment

Lighting conditions

Early observations suggested that chevrotains are nocturnal (Barrette, 1987), but more recent observations of free-living as well as captive individuals indicate that the lesser chevrotain is a predominantly crepuscular animal, with high levels of activity in the morning and late afternoon hours (Ahmad, 1994; Matsubayashi et al., 2003). All the 13 respondents of the survey are keeping their chevrotain in an enclosure with a diurnal light cycle (EEP survey, unpublished data, 2023).

Figure 24. Nocturnal chevrotain enclosure at Antwerp Zoo (former species holder). Photo courtesy of Dr. F. Vercammen.

Still, in some European zoos chevrotains have bred successfully under reversed lighting (EEP survey, unpublished data, 2007). The question about whether there are differences in e.g., activity level or breeding success between chevrotains kept in nocturnal houses and those which are kept in daylight houses are still unknown (Govers and van den Bergh, 1998).

Temperature and Humidity

Lesser chevrotains occur in subtropical and tropical lowland rainforest, where humidity is generally high, averaging about 80%, and where temperatures vary little throughout the year; the daily average lies between 23–30 °C, and the minimum and maximum temperatures do not differ much, ~20 °C and ~32 °C. As much as one would expect for these circumstances, chevrotains have little subcutaneous fat and their coat does not have the texture of a good insulating material (Whittow et al., 1977; Kamis, 1980).

Early experimental studies on temperature regulation and thyroid activity ascertained the lesser chevrotain's thermoneutral zone lying between 26.6 and 29.0 °C and a stable rectal temperature at environmental temperatures between 15 and 30 °C. Above 30 °C animals became hyperthermic whereas below 15 °C they were not able to maintain their body temperature anymore (Whittow et al., 1977; Kamis, 1980). In contrast, chevrotains at Cuc Phuong National Park, Vietnam, tolerate winter temperatures as low as 5 °C (day) or even 0 °C (night) for a couple of days.
Still, in a temperate climate, as is the case in most European countries, chevrotains will require heated housing and humidifiers, providing appropriate temperature and humidity levels, especially if housed (partially) outdoors. In this context attention should be paid to adequate ventilation: in at least two zoos, fairly high prevalences of pneumonia was suspected to be related to a bark substrate that was too moist and mouldy from suboptimal ventilation (EEP survey, unpublished data, 2007).

Table 9. Climate control data collected through the survey of 2023.

Institution	Min. temp. (°C)	Max. temp. (°C)	Climate control provided
1	17	26	Thermometers, vents and skylights
2	21	34	None
3	12	30	Heating and automatic roof
4	15	25	Recuperator
5	-	-	-
6	18	26	None
7	25	31	None
8	-	-	-
9	-	-	-
10	18	24	Ventilation and heatpanels
11	22	35	Automatic roof
12	17	-	Heating and open windows
13	20	25	Heating and open windows
14	22	25	Mechanical ventilation
15	22	28	Airconditioning
16	21-22	24-25	Hygro control

The minimum and maximum temperatures of 13 institutions are documented by the survey´s questions. These are listed in the table on the right (table 9). The minimum temperature recorded was 12 °C and the maximum temperature recorded was 35 °C. The data collected in 2023, does not vary much with the literature. It is important to mention that institution "7" only houses their lesser chevrotains outside and therefore has no control over the ambient temperature and humidity (table 9).

Outdoor Facilities

Taking temperature and humidity levels in their natural habitat into account as well as a chevrotain's bodily condition, access to outdoor enclosures needs to be restricted at institutions located in central and northern Europe. Appropriate visual barriers, and possibilities to hide are equally important in both indoor and outdoor areas. Floors such as concrete or sand should be avoided. In contrast hard-packed earth, grass and natural vegetation proved to be suitable substrates (EEP survey, unpublished data, 2007).

Figure 25. Outdoor enclosure at Colchester Zoo (former species holder). Photo courtesy of C. Saunders.

Boundary

Generally, when designing an enclosure for chevrotains, it should be kept in mind that chevrotains are very agile and quick animals, which tend to uncontrolled flight reactions, and which are prone to injure themselves in sudden bursts of panic. Wire-netting fences, sharp edges, etc. should therefore be avoided and smooth surfaces are preferred. Furthermore, as forest-dwelling animals chevrotains are made to move through dense vegetation and to slip through almost every hole.

Separation

Appropriately equipped separation means should be at disposal in case of aggression and at any rate, to separate offspring before attaining sexual maturity.

2.2. Feeding

Lesser chevrotains are ruminants. Based on feeding patterns and the morphology and physiology of their gastrointestinal tract (please see chapters 1.2 and 1.3), it was concluded that chevrotains tend to be 'frugivorous ungulates' (Heydon & Bulloh, 1997), 'selective feeders' (Medway, 1983; Nolan et al., 1995; Karasov, 2003; Farida et al., 2006), 'browsers' (Kay et al., 1979; Endo et al., 2002), 'highly selective browsers' (Janis, 1984) or 'concentrate selectors' (Kay et al., 1979; Hofmann, 1988; Vidyadaran et al., 1994; Agungpriyono et al., 1992, 1995). As could be demonstrated in experimental studies, the lesser chevrotain, selective because in need of high energy requirements per unit body weight, compensates changes in food composition by changes in feeding behavior and digestive physiology to ensure efficient digestion (Nordin, 1978 a,b; Kay, 1987; Nolan et al., 1995).

Lesser chevrotains are ruminants; although a primitive representative of the ruminantia, the gastrointestinal tract is likely to contain an amount of cellulotic microbes sufficient to allow chevrotains to consume and effectively digest fiber-rich food (see Nordin 1978a; Nolan, 1995; Kudo et al., 1995). The fruits they have (limited or variable) access to in their natural habitat (Ahmad, 1994; Heydon & Bulloh, 1997; Miura et al., 1997) are likely to contain a much higher percentage of fiber and substantially less sugar compared to the fruits, which are regularly available in captivity, and produced for human consumption (Oftedal et al., 1996).

Furthermore, the word "fruits" used in publications may not only describe fruits like banana, apple, cherries etc. but may be used in the botanical sense, and thus may also include more fibrous 'botanical products', such e.g., seed hulls (seeds comparable to French beans or long beans).

Determined under experimental conditions, the dry matter intake by lesser chevrotains ranged from around 30 up to more than 50 g DM/day, depending on the rations' composition (Nordin, 1978a,b; Paden and Nordin, 1978; Nolan, 1995), the digestible energy intake ranged from 532 kJ/day to 853 kJ/day (Nordin, 1978 a,b; Kay, 1979; Nolan et al., 1995).
The high energy intake of chevrotains can be accomplished by eating food items with a high nutritional value or by having a continuous access to food or a combination. Looking at the diets currently offered in zoos that perform well, food items readily available in zoos, the observed diet in the wild and the species' anatomic characteristics, a diet should be based on high-fiber browse and forage material relatively high in energy and relatively high in protein. The high level of dietary fiber combined with a high caloric intake in a ruminant is challenging.

Basic Diet

Twelve out of the 16 lesser chevrotain holders provided information on their diets in the surveys (see below). A further suggested diet for lesser chevrotains is provided below (Semrau et al., 2010):

- 50% browse, fresh or dried leaves, shrub, green vegetables
- 25% pellets browser, leaf eater, horse, rabbit
- 15% fruits high fiber fruits, carrots
- 10% insects, nuts, grains, etc.

Pelleted Feeds

Ten out of the twelve institutions that responded to the diet section of the 2023 survey are providing pellets in the diet (n=10) (Figure 26). The percentage of this diet part varies from 10% to *ad libitum*. Two zoos are not providing the animals with any pellets (n=2) from one institution its known that this is temporary, although the reason for this decision remained unknown. When looking at the provided diet sheets (n=7) various pellets are fed by different holders, the most used pellets are listed down below (EEP survey, unpublished data, 2023).

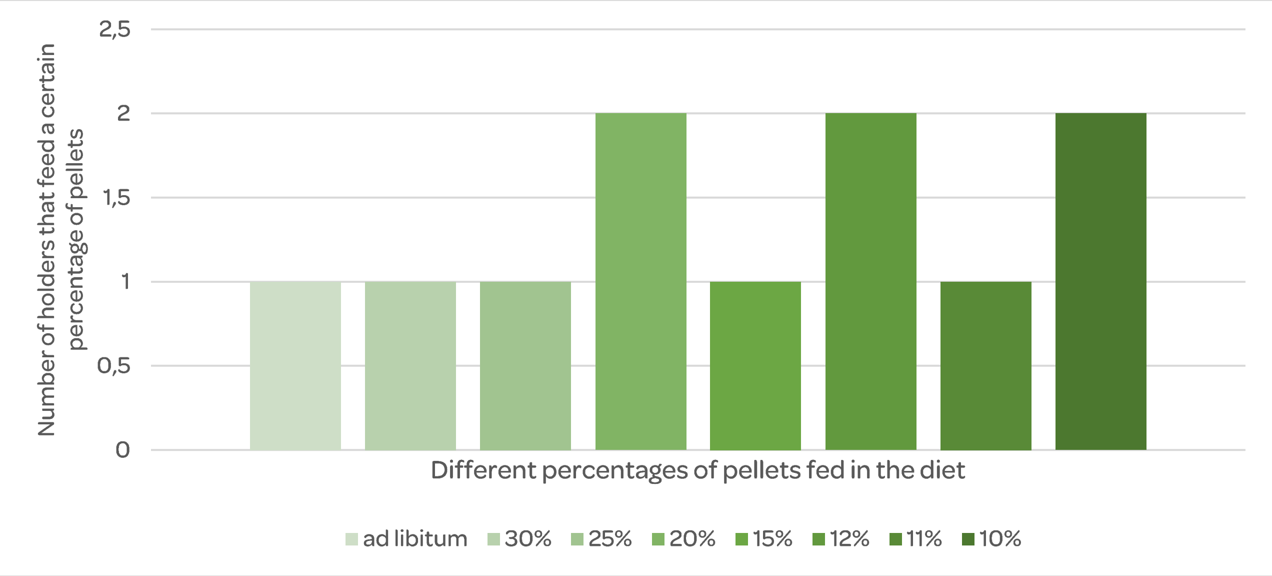


Figure 26. Percentage of pellets in the diet given to lesser chevrotains in the studied population of 2023.

- Browser pellets (Granovit® 4mm)
- Leaf eater pellets (DK Zoological® Leaf-eater pellets Small & Mazuri® Leaf Eater pellets)
- Herbivore pellets (Mazuri® Wild Herbivore Plus Diet pellets)
- Guinea pig pellets (Kasper Faunafood®)
- Rabbit pellets (Kasper Faunafood®)

Out of the ten pellet-feeding institutions only one holder offers a combination of pelleted feed products: the combination that is used are DK zoological® Leaf-eater pellets (small) with rabbit / guinea pig pellets (EEP survey, unpublished data, 2023).

Vegetables

The majority of holders provide around 60% vegetables in the diet (n=4) or more, at only one institution the diet consists 40% out of vegetables (n=1) (EEP survey, unpublished data, 2023).

Examples of vegetables that are incorporated in lesser chevrotains diets are:

- Carrot, celery, (red) pepper, cucumber, broccoli, turnip, lettuce, beetroot, endive, fennel, pumpkin, green peas, Brussels sprouts, cabbage. Important to note is that one institution stated to avoid feeding eggplant and leek (EEP survey, unpublished data, 2023).

Fruits

Out of the twelve lesser chevrotains holders, eight institutions are providing their animals with fruit. All eight holders provide 30% or less fruit in their chevrotain diets. The remaining four respondents do not include fruit as proportion in the diet (n=4). One institution noted that fruit is only given for enrichment purposes (EEP survey, unpublished data, 2023).

Examples of fruit that are incorporated in chevrotain diets are:

- Apple, pear, banana, papaya, tomato, grapes, pear, kiwi, melon, oranges, plums, and pineapple (EEP survey, unpublished data, 2023).

Browse

All 12 institutions that responded to the diet section of the 2023-survey, answered the segment about providing browse. The results are illustrated in Figure 27. At four other institutions the browse is given when its available (4), for example one institute is providing the animals in summer various types of dried raspberry leaves (Ad libitum). Another institute noted that when browse is available, the animals will get fed browse once a week. One institute noted that the dietary components of browse are incorporated in the pellets, therefore no additional browse was provided to these individuals (EEP survey, unpublished data, 2023).

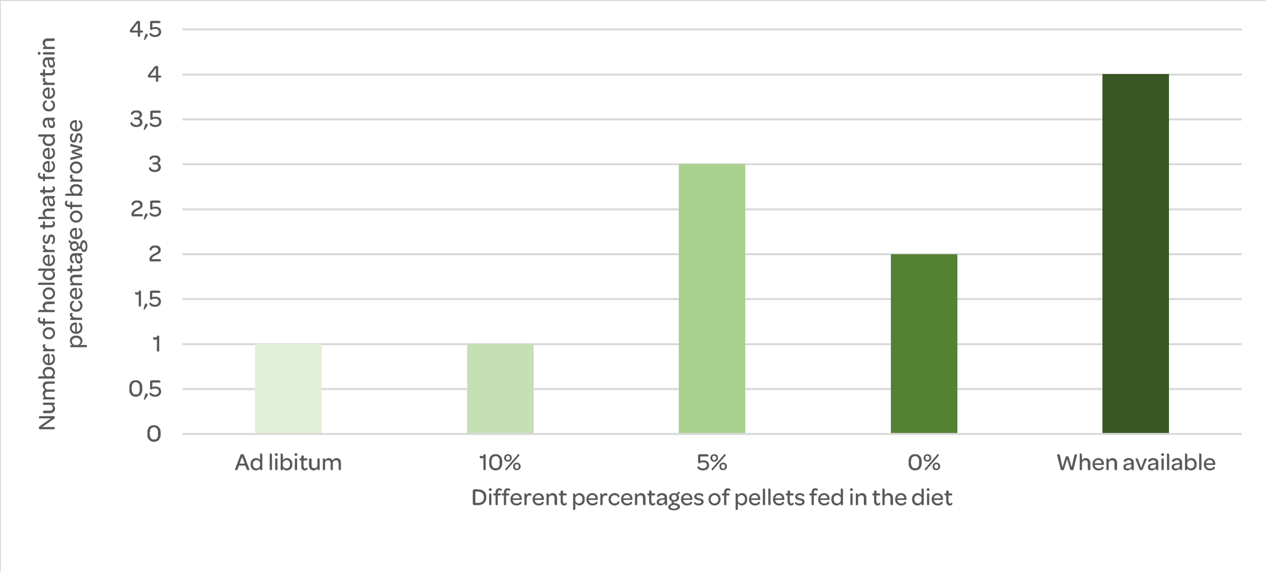


Figure 27. Percentage of browse in the diet given to lesser chevrotains in the studied population of 2023.

The question about the percentage of hay was answered by all 12 institutions. Six institutions provide hay *ad libitum* to their lesser chevrotains (n=6) while one of these institutes noted that their hay is mixed with alfalfa. At two other institutions the percentage of hay that is given is 5% of the complete diet (n=2). The remaining four institutions do not include hay in their diet (n=4) (EEP survey, unpublished data, 2023).

Eight respondents incorporated herbs in the diet of their lesser chevrotains (n=8). Two institutes are giving herbs ad libitum (n=2). At four institutions herbs are given when available (n=4), one of these institutions provides their lesser chevrotains with herbs up to three times a week as enrichment. For two institutes the component of herbs is 5% of the total diet (n=2). From one institution it is known that herbs are included in the diet, but unfortunately no percentage is given (n=1). The remaining four respondents do not give their animals any herbs (n=4) (EEP survey, unpublished data, 2023).

Examples of browse and foraging material that are incorporated in lesser chevrotains diets are:

- Dried raspberry leaves, alfalfa, hay, lucerne hay, willow, grass, dandelion, hibiscus, mulberry (EEP survey, unpublished data, 2023).

Additives

From the collected diet sheets, it is known that institutions are providing additives like: horse muesli (Equiral®), oats, wheat germs, linseed and St. Johns bread (EEP survey, unpublished data, 2023). Other additives such as protein are given by six institutions. The results vary and will be listed in decreasing order: 24% (n=1), 20% (n=1), 10% (n=1), 5% (n=2), 3% (n=1), 0% (n=4) and unknown (n=2). Four institutions do not include a protein component in their chevrotain diet.
Examples of protein components that are incorporated in chevrotain diets are:

- boiled egg (preferably quail), live insects (crickets, grasshoppers and/or mealworms) and tofu. Important to note is that these components are given by two institutions twice a week, and by one institution three times a week maximum (EEP survey, unpublished data, 2023).

Table 10. Dietary nutrient concentrations for captive ruminant concentrate selectors, based upon National Research Council requirements of domestic animals and research with wild/zoo animals (90% dry matter basis) (extracted from Lintzenich & Ward, 1997).

Nutrient	Quantity
Protein %	16-20
Vitamin A IU/G	1.0-3.5
Vitamin D IU/G	0.5-1..0
Calcium %	200-350
Phosphorus %	0.15-0.74
Magnesium %	0.10-0.44
Potassium %	0.09-0.18
Sodium %	0.45-0.80
Iron mg/kg	0.05-0.16
Zinc mg/kg	27-45
Copper mg/kg	10-30
Manganese mg/Kg	6-9
Selenium mg/ kg	0/07-0.18
Iodine mg/kg	0.09-0.72

Supplements

Mineral and vitamin intake has not been specifically measured in chevrotains and can be extrapolated from other species (sheep, goat, horse, rabbit, deer) and other species information sources.

In general ruminants do not require extra vitamin B, vitamin C and vitamin K. These vitamins are produced by the animal. Calcium and vitamin D and E deficiencies have been known to cause problems in lesser chevrotains in captivity. Average calcium content of a diet should be around 0.5-1% and the level of vitamin D3 ranges from 200-1000 IE/kg. Higher dosages of vitamin D would be preferred in situations with a lack of UV-light, i.e. either suitably intense and regular exposure to natural sunshine or artificial lighting which includes suitable levels of UVB radiation. Vitamin E levels range from 15-100 IU/kg and even in the higher dosage range an over dosage is unlikely to occur (Semrau et al., 2010).
Out of the twelve respondents that answered the supplement question, eight institutions provide a form of supplement to their lesser chevrotains (n=8).
The frequency that the supplements are added varies per respondent. Of the known frequencies, two institutes are adding supplements daily to the diet. Another two zoos are giving their animals supplements 4 times a week. One institution adds supplements 2 times a week. Lastly one institution is adding supplements every first ten days of the month. The remaining two respondents did not indicate the frequency of the supplement that was added to their chevrotain diets (EEP survey, unpublished data, 2023).
Further investigations, giving more insight into the dietary requirements of captive lesser chevrotain and into the relationship between nutrient intake and reproductive performance, digestive function, and disease processes are needed.

In summary, 12 zoos contributed data about their lesser chevrotain diets; typically, these diets are composed of a pelleted feed (n=10), vegetables (n=11) and produce such as fruits (n=8), browse (n=9), hay (n=8), herbs (n=9) additives like oats, seeds and muesli (n=3). Protein components are added occasionally by 6 holders, while 8 holders provide a form of supplements to their lesser chevrotains. An example of a recommended diet for lesser chevrotains can be found in Appendix III.

Special Dietary Requirements

Required protein levels or needs for essential amino acids may vary over time, especially related to growth and reproduction; higher protein levels of 115% dry matter (DM) content may be required during reproduction and lower levels (110% DM) during maintenance (Semrau et al., 2010).
In several zoos pregnant females have been observed to display an increased appetite and/ or to consume more water (6 out of the 15 holders), especially when food items rich in protein are fed. 30% (7 out of 23 holders) of lesser chevrotain holders increase the total amount of the diet when females are pregnant or lactating (EEP survey, unpublished data, 2007)
Results from the 2023-survey noted that 50% (6 out of the 12 holders) of lesser chevrotain holders change

the diet when females are pregnant or lactating. Five out of the lesser chevrotain holders change the diet between seasons to require their optimal metabolic needs (EEP survey, unpublished data, 2023).
In case of obvious weight loss, the addition of cooked rice to the daily diet is practiced and recommended by one institution (EEP survey, unpublished data, 2007). For juveniles it should be ensured that vitamin and mineral supplementations and are available on a daily basis; equally important are the provision of fiber-rich but palatable food items (EEP survey, unpublished data, 2007).

Diet-related Issues

A brief overview shall be given on affections and symptoms which were certainly or potentially related to the individuals diet, to the diets' composition or to single food items. Data derived from the 2007-survey and from a preliminary study on necropsy reports carried out at ARTIS Amsterdam Royal Zoo (for more information please see chapter 2.8); some issues were of single, others of more frequent occurrence, still, all diseases and/ or symptoms are listed below:

- sand intake leading to colic, obstipation, enteritis and/ or stasis
- phyto- and/ or trichobezoar leading to colic, obstipation, enteritis and/or stasis
- foreign bodies or food items leading to laryngitis, tracheitis, oesophagitis, reticuloperitonitis
- dental plaque
- paradontopathy, leading to abscessation and focal osteomyelitis
- hepatopathy, hepatic degenerations
- nephropathy, renal degenerations
- cardiomyopathy, myocardial degenerations
- tympanie
- ruminal acidosis
- foamy bloat
- inflammation and abscessation of salivary glands
- suffocation
- urolithiasis
- developmental disorder of the rumen
- adipositas/ cachexia; in contrast to the rare cases of adipositas or obesity (2/ 244), the diagnosis 'cachexia' was made remarkably often within necropsy reports; probably, this circumstance has to be regarded in relation to the generally lean statue of chevrotains
- decreased reproductive performance (dystocia, stillbirth, reduced viability of neonates)

M. van der Hage (1989) described a series of congenital cataracts, occurring in 14 out of 23 juvenile lesser chevrotains at ARTIS Amsterdam Royal Zoo, between 1981 and 1987; a dietary vitamin E deficiency was suggested as the possible cause.

Method of Feeding

To allow lesser chevrotains to perform their natural foraging behavior, feeding stations should be dispersed throughout the enclosure. This will also ensure that each individual has access to sufficient amounts of the provided diet. Eight out of the 22 institutions (EEP survey, unpublished data, 2007) provide at least one feeding location per animal.
However, it is necessary to make sure that chevrotains only have access to their own diet if they are kept in mixed species exhibits. As cases of weight gain up to adipositas, fatal ruminal obstruction by a dried raisin, ruminal acidosis and a high incidence of tooth root abscesses are reported and suspected to be related to lesser chevrotains consuming too much of other species' diets (EEP survey, unpublished data, 2007). It is therefore important to provide the other species in the enclosure with raised feeding stations if this is an appropriate feeding methods for this species. This to prevent the chevrotains from eating their diets (Figure 28).

Figure 28. Hanging feeding bowl for primates at ARTIS Amsterdam Royal Zoo, photo courtesy, K. Groot.

All responding holders provide their chevrotain diets in bowls (n=13) , eight holders are also providing food scattered on the ground throughout the enclosure to stimulate foraging behavior (n=8). The frequency of feeding varies per institution, two out of the twelve institutions are feeding their lesser chevrotains once a day (n=2). The majority of holders provide their chevrotains with food twice a day (n=7). The remaining three holders are feeding their animals up to three times a day (n=3). The majority of the diet should be fed in a bowl, as it is important to monitor the food intake of this species. However, a part of the diet (or certain diet items) can also be scattered around the enclosure to increase foraging time.

In view of the high ratio of 'sudden deaths' in lesser chevrotains (see chapter 2.6), but with respect to the fact that many chevrotains are kept in jungle-like mixed species exhibits, observation of food intake by each individual should be common practice for lesser chevrotains keepers. So far, 11 out of the 22 responding holders check the daily feeding, directly and/ or by monitoring/ weighing the leftovers (EEP survey, unpublished data, 2007).

Food enrichment is provided by nine of the thirteen institutions (n=9). The results are daily (n=5), weekly (n=4), rarely (n=1), never (n=3). Food items provided for enrichment are browse, vegetables, fruits, and herbs. These items can be scattered or distributed in piles throughout the enclosure. More uncommon items for food enrichment are insects, eggs, tofu, and St. Johns bread. Food enrichment should be varied and non-repetitive retain interested by the animals (EEP survey, unpublished data, 2023). Food enrichment should ideally be provided daily and be different every day.

Water

A source of fresh and clean water should be accessible for lesser chevrotains at all times. This can be in the form of pools, ponds or rivers integrated into the enclosure; in addition, a simple watering trough or a bowl can be provided as a source for water intake.

2.3. Social Structure

Basic Social Structure & Changing Group Structure

Considering the average enclosure size, a lesser chevrotain's solitary lifestyle, their tendency to a facultative monogamous/ polygynous social structure (Matsubayashi et al., 2006) and their intolerance towards same-sex individuals (Ahmad, 1994), it is recommended to keep lesser chevrotains solitary or in breeding pairs (Semrau et al., 2010). Alternatively, provided that sufficient space and visual barriers are given, it may be attempted to keep one male with more than one female in a harem-situation as is practiced at the Singapore Zoo.

Following previous experience of survey respondents from 2007, 5 out of the 16 institutions found that animals can be (re-) introduced irrespectively of the sex of the resident animal, whereas three holders prefer to introduce the male to the female and 4 out of the 16 holders prefer to introduce the female to the male. Another 4 holders usually introduce a pair in a neutral area. Direct contact between unknown individuals for the first days is avoided by several holders (n=4); they only allow visual, olfactory and auditory contact. Irrespective of the sex of the resident individual but based on information of their natural behavior and the experience made in different zoos, it is recommended to allow prospective mates several days of acquaintance prior to direct contact.

Almost every institution is keeping their animals in pairs or is waiting for a recommendation from the EEP coordinator (EEP survey, unpublished data, 2023). Related groups are common among the thirteen holders (n=7). Juveniles can be part of the group until sexual maturity is reached. All survey respondents are keeping individuals paired together at all times, unless medical attention is required. The institutions that keep bigger groups (with or without related individuals) will not always keep this structure intact. Four holders have answered that when offspring disturb potential mating attempts, or reach sexual maturity, they will be separated. Lastly, one institution will change the group structure by separation only when necessary, i.e. when special medical care is needed, or aggressive behavior is observed. De Figueiredo et al. (2021) found that the time pairs spent in close proximity had a negative effect on breeding success, but animals in more vegetated enclosures spent less time in close proximity to each other. Results could be partially explained by the natural habitat of this usually solitary species, i.e. tropical forest which provides local water sources and undergrowth for cover from predators. It is therefore recommended to keep chevrotains in densely planted enclosures to give this solitary species higher standards of welfare (Lemos de Figueiredo et al., 2021).

Aggressive behavior was observed in 7 of the 16 holders from the 2007 respondents. Six holders answered that aggressive behavior was usually observed from male to male, and only one added having also observed aggressive behavior among females. As could be expected, in most cases attacks were , directed from the older to the younger animal, and started when the latter was weaned and about to reach sexual maturity. Attacks towards young, which were still nursed as well as the opposite direction, a younger, immature individual attacking the older one were only observed once. Accordingly, it may become necessary to separate young earlier then usually happens in the wild, especially juvenile males, before they reach sexual maturity.

Sharing Enclosure with Other Species

The majority of the thirteen holders responding to the 2023 survey keep their chevrotains with other species (n=12). Chevrotains can be kept with a variety of species, the largest species group that coinhabit with chevrotains is formed by birds (n=9). Combination with mammals like binturongs, squirrels, sloths, flying foxes and primates of the New World are practiced by 7 out of the 13 responding zoos. Elsewhere chevrotains are mixed with reptiles like tortoises and different kinds of lizards (n=4). No amphibian or fish species were listed by the respondents of the survey. Remarkably, one institution is holding their chevrotains in a mixed exhibit with species of butterflies (Lepidoptera). All the institutions that participated in the survey are listed in Appendix II, including their respective enclosure dimensions.

The results from the questionnaire from 2023 are similar when comparing the data with the survey from 2007. Bird species are in both questionnaires combined with chevrotains at 70% of the institutions. When looking at mammal species that are housed with chevrotains, results are 54% in 2023 and 50% in 2007. When looking at reptiles and amphibians 31% of the holders combine them with chevrotains in 2023 and 35% in 2007. No fish species were listed in the 2023 survey, while the survey from 2007 found that fish were combined with chevrotains at 25% of the responding institutions.

It should be noted that the species listed in Appendix II are examples of species that have been successfully combined with lesser chevrotains. However, this cannot be guaranteed in every situation. To prevent any potential problems, species should be matched and introduced with care when housed in a mixed exhibit.

The 2023 survey respondents were asked what was considered when choosing certain species to mix with lesser chevrotains. Nine out of thirteen institutions looked at behavior characteristics when choosing the right species (n=9). Three institutions are choosing certain species based on the ecology of the animals (n=3). Eight institutions followed the husbandry guidelines from 2010 when selecting animals for their mixed exhibit (n=8). At ten institutions the space availability was taken into consideration when choosing species (n=10). Only one holder selects species that have a similar diet to the lesser chevrotain (n=1).

Figure 29. Example of a mixed exhibit in Pairi Daiza, Cambron, chevrotains are combined with the Sulawesi bear cuscus *(Ailurops ursinus)*. Photo courtsey of A. van Dijk.

The prospect of cross-contamination with parasites and diseases seems to be of little influence in the species combinations reported, provided that proper veterinary screening and health precautions are performed before introduction and on a regular basis (EEP survey, unpublished data, 2007).

Seven out of the 13 institutes (n=7) that responded to the 2023 survey observed interactions between their lesser chevrotains and other species in a mixed exhibit. Antagonistic behavior occurs at all seven zoos but only at low frequencies. Of these 7 holders, 6 reported that antagonistic behavior is rarely observed between species.

Interestingly, one zoo reports that their lesser chevrotain allows small birds to ride on their back and groom their fur. In another institution a young female was observed peacefully sharing its den with a young two-toed sloth. In contrast, aggression was observed in a 20 m^2 measuring enclosure shared by lesser chevrotains, pygmy slow loris and large tree shrews; the chevrotains displayed aggressive behavior towards tree shrews to an extent that the latter had to be removed from the enclosure (EEP survey, unpublished data, 2007). Inter- or intra-specific aggressiveness with fatal outcome for chevrotains were suspected to be the cause of death in two cases of necropsy reports studied (please refer to chapter 2.6); both animals died 'suddenly' and showed signs of repeated trauma at postmortem.

Species that are reported to be a problem when housed with chevrotains are the Goeldi's marmoset (*Callimico goeldii*), spotted whistling duck (*Dendrocygna guttata*), Mindanao lorikeet (*Trichoglossus johnstoniae*) and the red-billed blue magpie (*Urocissa erythrorhyncha*) (EEP survey, unpublished data, 2023).

To avoid any aggressive behavior between species, access to a separation area is advised. Only two out of the thirteen holders are providing a separation area for their lesser chevrotains (n=2). At one of those two holders the chevrotains share the enclosure with a muntjac (*Muntiacus muntjac*), a place that is only accessible by the chevrotains in this situation is necessary. The access to a separation area is always accessible at eleven holders, only two holders answered that they are controlling the ability to separate the animals. At none of the thirteen responding zoos are the animals concealed overnight from other species or while feeding (EEP survey, unpublished data, 2023).

As the majority of holders keep their lesser chevrotains in aviaries mixed with different bird species, it seems to be of utmost importance to report that Puschmann (2004) suspects chevrotains to occasionally capture the young of ground-nesting birds. Conversely, necropsy reports show that a captive chevrotain was killed by a captive Cuban crocodile in the past.

2.4. Breeding

Mating Pregnancy and Birth

Lesser chevrotains breed and give birth year-round. Cycle length from females is approximately 14 days with estrous lasting for about 24-48 hours. Gestation is about 4.5 months, but lengths reported vary considerably. Parturition usually takes place in the early morning hours. Females have a post-partum estrous, and new mating attempts will occur within the first 24-48 hours after parturition. The number of offspring is usually one young while twin births are rare (Kamis et al., 1994; Kudo et al., 1997).

Figure 30. Mating chevrotains at ARTIS Amsterdam Royal Zoo. Photo courtesy of P. Feddema.

Pregnancy can be difficult to detect visually until late in gestation. From the 2007-survey (n=23) it can be reported that 65% (n=15) of responding institutions observed physical or physiological changes in pregnant females. Abdominal enlargement becomes obvious from around one month before birth (n=15) and females may demonstrate an increase in appetite (especially proteins) (n=5) and water consumption (n=1). Fetal movements (n=4) as well as a mammary development (n=3) may be seen a few days prior to parturition (EEP survey, unpublished data, 2007). Kudo et al. (1997) observed a tendency in females to sit most of the time before parturition. Close observation of mating behavior and measuring intervals between preceding, successive parturitions are useful tools to predict pregnancy and birth (EEP survey, unpublished data, 2007). Six out of the twelve institutions that answered the survey from 2023 reported that they change the diet when females are pregnant (EEP survey, unpublished data, 2023).

Newborns usually appear in dorsal sacral position, anterior presentation and, in contrast to most other ruminants, with one or both front legs extended along the rump. After birth the dam should remove (and eat) the neonate's membranes (which usually occurs straight after birth) and the infant should be on its feet and suckling within the first hour (Semrau et al., 2010).

Weight at birth is relatively high, it may reach more than 10% of the dam's body mass; weights reported range from 120 to 250 g (Kudo et al., 1997; Robin, 1988). Several cases of dystocia, cases of torsio and prolapsus uteri and rupture of uterus and umbilical cord are documented. But cases of caesarean sections have also been reported, although outcomes of these procedures vary; several problems occurred at a later stage due to e.g., incomplete wound healing, wound infections or post-partum retention of urine for unknown reasons (EEP survey, unpublished data, 2007).

Development and Care of Young

As described in chapter 1.7, young remain hidden in the vegetation for the first days except for short nursing periods. In 1987 it was hypothesized that a high perinatal mortality in captive populations may also be due to insufficient hiding possibilities (Dekker and Schmidt, 1987). Exhibit and environmental factors which can be hazardous to newborns such as e.g., enclosure structure, temperature, water features (pools, ponds and rivers) or the presence of heterospecifics in or near the exhibit should be considered when offspring is expected.

Figure 31. Dam and offspring at ARTIS Amsterdam Royal Zoo. Photo courtesy of R. van Weeren.

Robin (1979) observed nursing about 12 times per day at two days of age, about five times at about a week and about three times per day at two weeks of age. Periods of suckling lasted from three to six minutes. Grooming and care of the infants anogenital region are important elements of the mother-calf relationship and crucial for the newborn's urination and defecation. At about seven days of age, young start following their mothers and at the end of their second week they consume solid food (Robin, 1979; EEP survey, unpublished data). Young are weaned at about three months (10-13 weeks) (Robin, 1979; Kamis et al., 1994; Karasov, 2003) and reach sexual maturity at three to five months of age (Kamis et al., 1994; Kudo et al., 1997). Kudo and colleagues (1997) observed copulation at the earliest age of 166 days in male lesser chevrotains, earliest age of conception and first parturition of females at 125 resp. 258 days of age.

The 2023 survey found that it is not standard practice to separate females from their exhibit-mates when pregnant (n=12). At one institution the subadults will be separated when necessary (EEP survey, unpublished data, 2023). The 2007 survey found that 2 out of 16 responding zoos separate the pregnant female at some point prior to parturition, one of them keeps dam and offspring isolated for about 12 weeks (EEP survey, unpublished data, 2007). Whether separation of a pregnant female or a female with newborn is necessary depends on the male's character, in individual cases a male may attack a newborn, whereas another is very tolerant. Newborns staying in close proximity, even direct physical contact to the male while the female was foraging where observed (EEP survey, unpublished data, 2007). Only one out of the thirteen 2023-survey respondents reported that signs of aggression towards a new-born by a sire or dam has been observed (n=1). Four holders reported that it was unknown if this situation took place in the past at their institution (n=4). The other holders never experienced these circumstances with their animals (n=8) (EEP survey, unpublished data, 2023).

Figure 32. Offspring of the lesser chevrotain a few days after parturition. Photo courtesy of E. Butter.

When asking if any problems occurred with bonding between the new-born and dam, most of the institutions reported that they did not experience this problem (n=10). Only one institution reported that they have experienced bonding problems between dam and fawn (n=1). The reason for this bonding problem is unknown as the bonding process can be affected by a variety of factors. The level of this influence is different per individual. At the two remaining holders this situation was unknown (n=2) (EEP survey, unpublished data, 2023).

When juveniles reach the age of sexual maturity they should be separated from sire and dam. Eight out of ten institutions have responded to the 2007 survey. The male will be separated at the offspring's age of 10 weeks to 6 months; two respondents let juvenile males stay with the group until 10 to 13 months of age (n=2). Female offspring is separated at some point between 9 weeks and 5 months after giving birth by 7 out of 10 responding zoos. Only one zoo let the young female stay longer than a year. If no male is present, female offspring may stay with the dam as long as needed, provided that sufficient space and visual barriers are available (EEP survey, unpublished data, 2007).

Results from the 2023 survey question found that (n=13), the age that male offspring is separated ranges between 2.5 and 6 months after birth of the young. The results of the survey will be listed in increasing order: 2.5 months (n=1), 3-4 months (n=1), 4 months (n=2), 4-5 months (n=1), 5 months (n=1) and 6 months (n=2). The other five zoos listed "not applicable" due to the lack of offspring (n=5) (EEP survey, unpublished data, 2023).

For female offspring the separation age that holders utilize is nearly identical to male separation age. The age that female offspring will be separated ranges from 2,5 to 7 months. The results of the survey will be listed in increasing order: 2.5 months (n=1), 3-4 months (n=1), 4 months (n=2), 5 months (n=1), 6 months (n=2) and 6-7 months (n=1) As mentioned above, the same five zoos responded with "not applicable" due to the lack of offspring (n=5) (EEP survey, unpublished data, 2023).

Individual Identification and Sexing

Accurate and consistent recognition of individual animals are the basis for every activity of captive management. As in many other species, the time of sexual maturity especially in males is hard to define, since prolongation of body growth relative to sexual maturation is common (Kirkwood and Mace, 1996); in chevrotains the intermandibular gland of males only starts developing at about 4.5 months of age concomitant with the onset of sexual maturity, the prominent canines do not extend beyond the upper lip until the animals are about nine to ten months old. As an alternative, by carefully picking up the young, sexing during the first 48 hours after birth is possible: scrotum and prepuce or four inguinal mammary glands are clearly visible (personal communication M. Versloot and J. Jansen, ARTIS Royal Zoo, Amsterdam). It is recommended that the implantation of a transponder for identification purposes is should not be applied before adult size is reached.

When requesting information about handling neonates in the 2023-survey, five out of the thirteen respondents mentioned that they are handling neonates (n=5). Out of the five holders that handle neonates only one institution will handle the neonates more than once. Most neonates are handled for sex determination and health examination. The other eight institutions are never handling neonates (n=8), the reason for this, however, is not mentioned by holders (EEP survey, unpublished data, 2023).

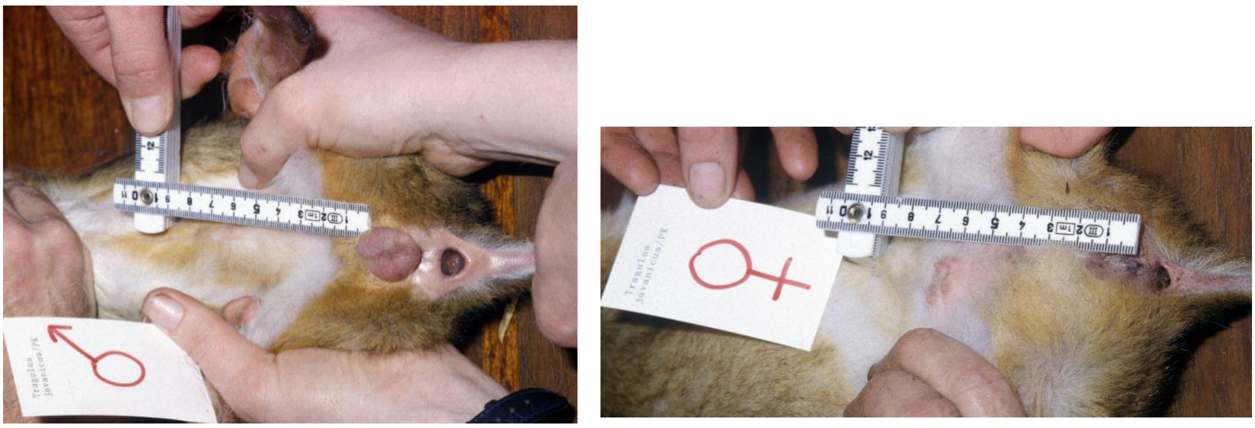


Figure 33. Sexing of adult animals at ARTIS Amsterdam Royal Zoo, photo courtesy of R. van Weeren.

Thirty-day-mortality of both sexes of chevrotains between 1970 and 2008 was ascertained as 36.4% (296 of 814 neonates). The full results (including adult animals) of the necropsy study can be found in chapter 2.7 Considerations for Health and Welfare. Preliminary results of a retrospective study on circumstances and causes of death in 66 (28.21.17) chevrotain infants are presented in the following paragraph: For 33 % of newborns pathological records did not provide information on the circumstance of death ('unknown') and in 32 % of documented cases death occurred 'suddenly'. 'Other' circumstances included, e.g., fatal traumatic injuries by someone who stepped on the newborn chevrotains or deaths of hand-reared animals.

In 12% of dead neonates the primarily affected organ system could not be identified; 'generalized' comprises stillbirth and starvation from insufficient supply of mother milk and/or lack of maternal care.
For 17% of death in neonates the aetiology was not evident, for 34% death was suspected to be primarily caused by insufficient supply of mothermilk and/or maternal care. Cases of stillbirth were aetiologically categorized as a genetic or prenatal event, but there is little evidence that the aetiology of these events has been investigated any further. Predominant disease of primary or secondary infectious aetiology was colisepticaemia, but also infestations like e.g., salmonellosis, klebsiellosis and pasteurellosis were seen.

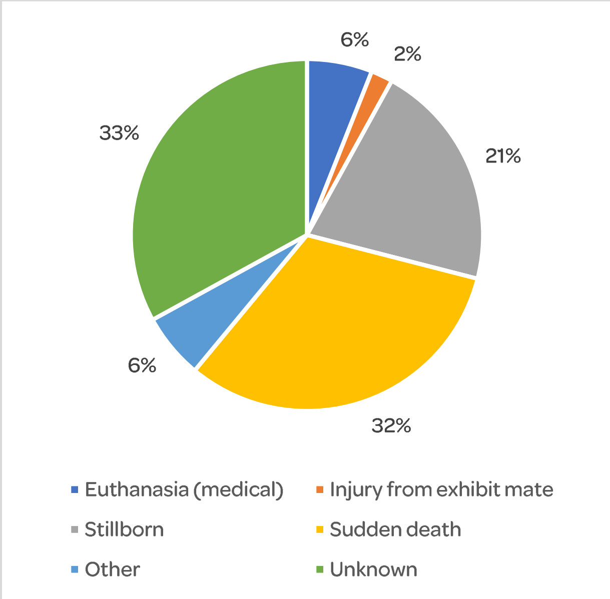


Figure 34. Circumstances of death, (EEP survey, unpublished data, 2007).

Results of this preliminary summary give first insight into infant mortality of captive lesser chevrotains. The majority of deaths in newborns were suspected to be primarily caused by insufficient supply of mother milk and maternal neglect. Regarding the current status of the captive population in European zoos, close observation of dams and offspring seems to be required. Little information can be found in literature, but Wharton (1987) noted an increasing survival rate of *T. napu* offspring at the Bronx Zoo, New York, after it had become routine to install heat lamps in one corner of the enclosure and the application of a multivitamin injection to every neonate.

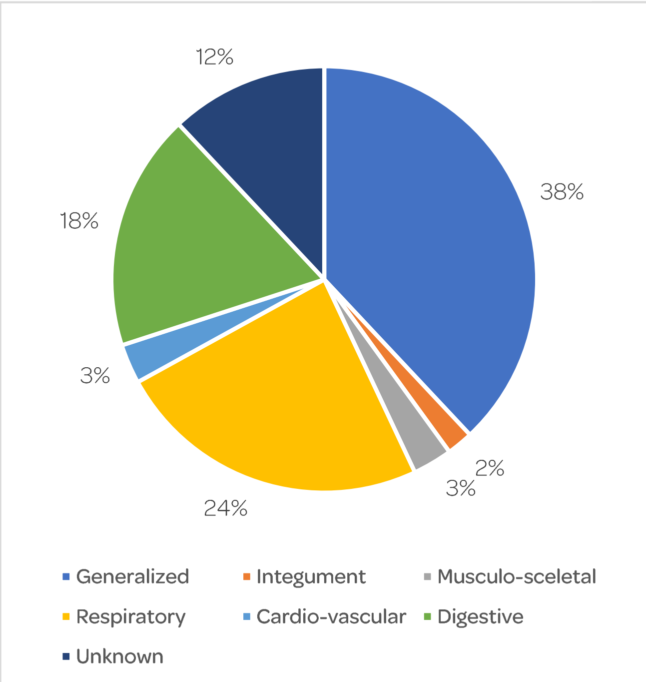


Figure 35. Topography, (EEP survey, unpublished data, 2007).

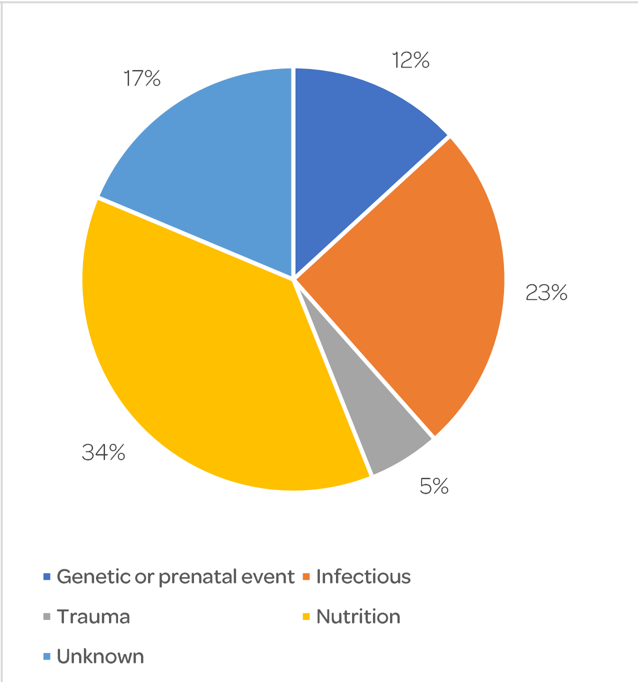


Figure 36. Aetiology, (EEP survey, unpublished data, 2007).

Hand-Rearing
Despite all precaution taken to ensure that environment, diet and social conditions are optimal for the pregnant female, neonatal or maternal problems may require the application of hand-rearing techniques as an emergency measure. Detailed advice on neonatal care and hand-rearing in general can be found in literature (e.g. L.J. Gage's 'Hand-Rearing Wild and Domestic Mammals' or 'Wild Mammals in Captivity' by Kleimann et al.), but little is published specifically on the lesser chevrotain. A result of milk analysis is performed by Romer (1974); the sample derived from a single female, which died on day 21 post-partum. In this lactation period milk contained 63% water, 26.8% fat, 6.4% protein, 0.4% lactose and 1.1% ash, details on its constituents are lacking.

Since so little information is available, experiences on hand-rearing were asked for in the survey of 2007; 14 out of 23 responding zoos answered not to have experience, but four institutions reported having at least tried to hand raise a lesser chevrotain orphan. Lambmilk with Bioserin® (WDT, Wirtschaftgenossenschaft Deutscher Tierärzte eG) fed every 4 hours helped to keep the chevrotain alive. Another neonate, which was fed 3 to 6 times a day with Nutrilon® (Nutricia, Nederland BV), developed normally in the beginning, but died at 12 days of age for an unknown reason. In a third case the young died already at two days; it was suspected that nursery personnel did not intervene quick enough.

Figure 37. Lesser chevrotain orphan at Leipzig Zoo, photo courtesy of Prof. Dr. K. Eulenberger.

A description of a successful case of hand- rearing was published by Allwetter Zoo Münster, Germany (Adler, 1994); this report provides useful information on some practical aspects of hand-rearing such a tiny animal. The female young was 5 days of age and weighing ~200 g, when its mother died. At first, droplets of milk supplement (not specified) were offered from the back of the keeper's hand, but soon after, on the same day, the young accepted being fed with bottle and nipple commonly used for puppies. Wrapped in a towel, the infant was fed 4-6 times a day for about three weeks and started to consume leaves, fruit, and grass at the age of about two weeks. After every feeding the young was stimulated to defecate and urinate by gently rubbing its anogenital region with a soft rag. At the age of about seven weeks the young had doubled its weight and was successfully re-introduced into the exhibit.

In view of the present situation of the population in European zoos, the survival and (genetic) contribution of every individual may prove necessary. Close observation of dam and offspring, and, considering individual situations, medical intervention in time seem to be required.

2.5. Behavioral enrichment

Enrichment
Different enrichment varieties can be provided for this species, for example food enrichment, physical enrichment, and olfactory enrichment. Ten out of the thirteen respondents are providing their chevrotains with a form of enrichment (n=10). Physical and olfactory enrichment is discussed in 2.1 Enclosure under "Furnishing and Maintenance". Food enrichment can be found in chapter 2.2 Feeding, under "Feeding Methods". It is important to mention that social behavior may be encouraged through mixed species exhibits when interspecies interactions occur, more information can be found in chapter 2.3 Social Structure, under "Sharing Enclosure with Other Species" (EEP survey, unpublished data, 2023).

Training

Depending on the general policy of the institution, hand feeding may be prohibited by certain institutes. However, hand feeding provides the chance of close visual examination, especially in those enclosures which do not facilitate an inspection from a distance, drugs can be administered and/ or the animal lured on scales for weight control (EEP survey, unpublished data, 2007). Chevrotains can be trained most effectively through positive reinforcement training (as for other ungulate species, see Weerman & Van de Bunte, 2020). Through training, stress can be minimized in situations that are normally perceived as very stressful for chevrotains. For example, when animals are trained to walk voluntarily in the transport crate, restraining the animal will not be necessary. Nine out of the thirteen 2023-survey respondents are training their chevrotains (n=9). Two holders are training the animals daily (n=2). Four institutions are training their chevrotains weekly (n=4), and three other zoos are training opportunistically (n=3). The remaining four institutions are not training their animals (n=4). (EEP survey, unpublished data, 2023).

Out of the nine zoos that are training their animals, four are training chevrotains to approach staff voluntarily (n=4) Two institutions are training their chevrotains to walk into a transport crate voluntarily (n=2). One other institution is only training their animals to come into a specially designed shelter voluntarily. The remaining two holders are training multiple goals at the same time, one is training for a voluntarily physical check and walking into a transport crate. The last holder is practicing scale training, medical training, and crate training.

The animals can be stimulated with food for successful participation. Known food items that can be used in training are peas, grapes, and sweetcorn (EEP survey, unpublished data, 2023).

Figure 38. Scale training with chevrotain (collected from EAZA Animal Training Guidelines, 2023).

2.6. Handling

Catching & Restraint

Depending on the general policy of the institution, hand feeding animals may be in sharp contrast to their animal interaction and husbandry policies. However, hand feeding provides the chance of close visual examination, especially in those enclosures which do not facilitate an inspection from a close distance (if animals are kept in large and foliage dense enclosures), drugs can be administered and/ or the animal can be lured on a scale for weight control (EEP survey, unpublished data, 2007; 2017; 2023).

Physical Restraint

When handling is required, care should be taken to avoid obstructions in the animal's path as in sudden bursts of panic, animals may injure themselves, and abrasions, cuts, broken canines, etc. will be inevitable. Wharton (1987) recommends cages of small dimensions for capture, since under these conditions, the animals are unable to build up a great deal of velocity during moments of panic. When stressed, chevrotains might be soaked with sweat or even go into a state of shock (Hauser et al., 1981). Hence, good planning, teamwork and proper handling right after capture are essential.

Hands-on restraint as well as the use of nets should be avoided. Due to a chevrotain's tiny statue, the animal may get entangled in a net's gaps when trying to free itself, which implicates a high risk of severe injuries on back, legs or hip. Furthermore, direct contact leads to excessive stress, and cases of sudden death within 90 seconds were reported (EEP survey, unpublished data, 2007; 2023). Thirdly, although injuries caused by a chevrotain might not be life threatening, the handler can be hurt badly by males slashing with their canines. The adjoining picture shows a scar on a para-veterinarian's forearm (preceding were two sessions of plastic surgery) caused by a panicking male lesser chevrotain. When hands-on restraint must be performed, the chevrotain should be seized as quickly as possible and clutched to the handler's chest with both arms pinning the animal's legs and body in a firm, but gentle restraint.

Figure 39. Injury caused by the canines of a male lesser chevrotain, photo courtesy ARTIS Amsterdam Royal Zoo.

A safer way of restraining the animal is the usage of a bag or gunny. Using a bag, animals may be caught when jumping or be cautiously driven through a tunnel into the bag. Prior to transport or anesthesia via induction chamber, chevrotains can be driven through a tunnel into the respective box. Alternatively, the animal can be allowed to become accustomed to the box in advance, so that simply closing the door is all that is necessary (Wharton, 1987; EEP survey, unpublished data, 2007). Finally, immobilization from a distance by use of a blowpipe has been practiced for the immobilization of lesser chevrotains but should be avoided as the risk of trauma by the anesthesia dart is too high.

Figure 40. Equipment for physical restraint of Lesser chevrotain, photo courtesy of A. Semrau.

Chemical Restraint

Lesser chevrotains are very sensitive to stress, trauma and respiratory depression. For this reason, it is important to avoid capture and anesthesia when possible, and to reduce the stress, and time of restraining and anesthesia to a minimum. Inhalation of isoflurane proved to be the method of choice for general anesthesia without any analgesia, which is suitable for minor, non-painful actions. Training the animal to come into a sealed box and then administering gas into this box causes minimal stress and is the recommended way of induction (Figure 41). Regurgitation and sudden death during anesthesia is not uncommon in this species. Therefore, it is important to avoid regurgitation and to avoid too deep anesthesia, it's important to continue the gas-anesthesia via a face mask or tracheal tube as soon as possible after recumbency to have better monitoring. When a face mask is used, pulling out the tongue prevents inhalation of rumen fluids in case the animal regurgitates. Similar to other ruminants it is important to keep the animal in sternal position, or when lateral, recumbent with the head higher than the rumen, as much as possible. Dorsal recumbency should be prevented, if possible, similar as in other ruminants. Induction of anesthesia can be performed with 4-5 Vol.% of anesthetic gas in the induction box, followed by 0.5 - 2 Vol.% for maintenance by a face mask or inhalation tube. If the procedure is likely to be painful an additional analgesia should be administered, similar to other species. In this species continuously monitoring breathing is crucial, because respiratory depression and apnea has frequently been reported. Monitoring the depth of the anesthesia by close observation of the anaesthetist and additional pulse-oxy-meter is highly recommended. Additionally, capnograph and ECG can be used.

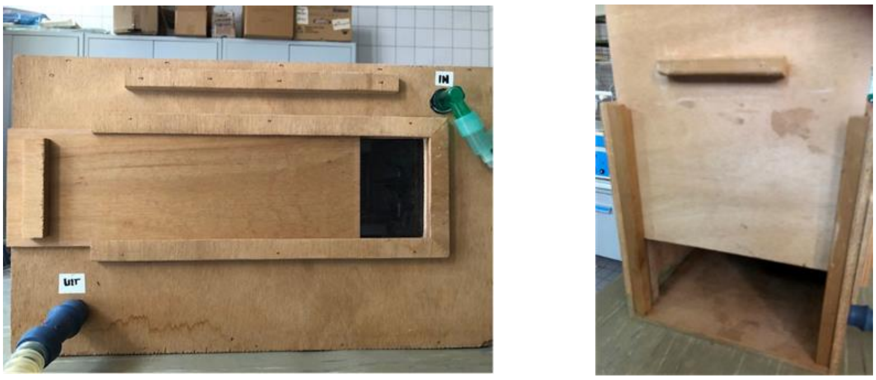


Figure 41. Induction box with two openings (IN and OUT) to be able to administer gas anaesthesia in the box. A window makes it possible to inspect the animal inside the box without causing too much stress.

Alternatively, or when no gas-anesthesia machine and/or induction box is available, anesthesia can be achieved by intramuscular hand Injection of an Alpha2-agonist with Ketamine. The following dosages have successfully been used in zoos:

2.0 – 2.5	mg/kg BM	Ketamine
0.06 – 0.08	mg/kg BM	Medetomidine
Reversal agent:	0.3 – 0.4 mg/kg	Atipamezole

Tranquillization

For short-acting tranquillization, if necessary, at all, Azaperone (Stresnil®; up to 0.5 mg/kg BM, i.m.) may be administered. Long-acting tranquillization may be achieved by intramuscular application of Perphenazine enanthate (Trilafon®; 1-2 mg/kg BM, i.m.); however, as long as the animal is kept calm in a dark box, tranquillizer are rarely necessary.

Transportation

For short distances (e.g. walking distance), chevrotains may be carried in a capture bag or gunny. Longer distances in contrast should be performed with the animal being safely locked up in a padded crate or box with tempered light (see figure 42). This crate is used for chevrotain transportation. A few modifications are made, the transport crate is a bit smaller than normal, the animals were observed and looked more calm/ comfortable than being transported in a bigger crate. The measurements should be 30 x 50 x 30 cm (width x depth x height). The ceiling is padded with foam rubber to reduce the possibility of trauma. In the past the animals did not show interest towards the foam rubber, but this is no guarantee and hence observations are always needed (EEP survey, unpublished data, 2023).

In this context it seems to be noteworthy mentioning the result of an early study undertaken at the Institute of Veterinary Pathology, Vet Suisse Faculty Zurich: although transportation was not a problem, five out of seventeen animals died from shock within the first three weeks after import (Hauser et al., 1981). Authors suggested that it seems to be especially important to provide calm surroundings for chevrotains while they are quarantined, respectively while they are adapting to their new environment.

Five out of the thirteen institutions responding to the 2023 survey experienced situations where animals suffered from trauma due to transportation (n=5). Two institutions responded that 20% of transported animals have suffered from trauma (n=5) in their experience. Another two institutions have mentioned that they experienced a trauma risk of 5% (n=2). The remaining holder did not indicate a percentage but mentioned that trauma happened rarely in the past when transporting animals (n=1). The other eight zoos had not experienced problems due to transportation (n=8) (EEP survey, unpublished data, 2023).

Figure 42. Transport crate that is used and modified for chevrotains, photo courtesy of ARTIS Amsterdam Royal Zoo, 2023.

Diagnostics

The diagnostics for the health screening and diseases of chevrotains are similar to other ruminants, taking into account their small size, and the unique anatomical and physiological features mentioned before (chapters 1.2 and 1.3). Blood samples can be collected best under general anesthesia from the jugular vein with a bent small needle and 1 ml syringe. The neck needs to be bent slightly away from the needle, similar to collecting blood in cattle (Figure 43). Other venous access might be possible from the vena radialis, vena saphena lateralis or the vena cava cranialis. In this species collecting blood can sometimes be challenging. Increasing the blood pressure by administrating subcutaneous fluids approximately 10 minutes in advance might be of help when collecting blood is difficult in certain individuals. In some cases, it might be necessary to put the animal in dorsal recumbency for a short while to be able to find a jugular vein; however, it is safer to keep the animal in lateral recumbency if at all possible (see figure 43).

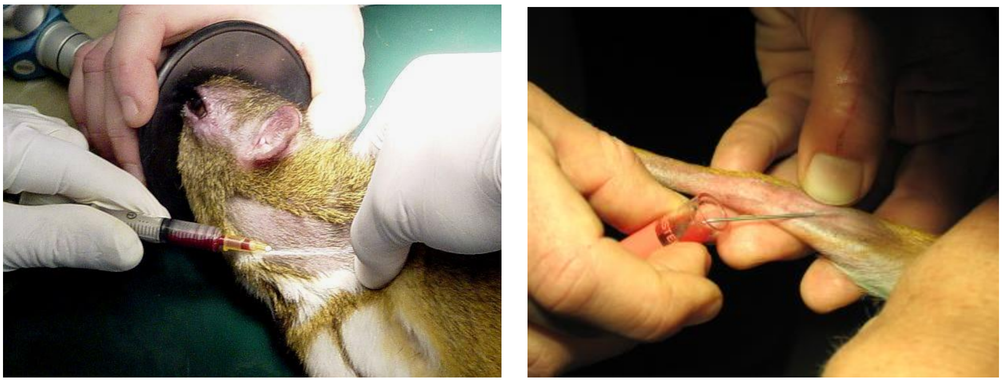


Figure 43. Sites for blood sampling, photo courtesy left, M. Hoyer & right, A. Semrau.

It appears noteworthy that red blood cell counts of lesser chevrotains can usually not be ascertained by automatic cell counters - depending on the principle of the instrument respectively as long as the instrument is not calibrated especially for this species. Due to the extremely small size of erythrocytes in lesser chevrotains (please refer to chapter 1.3) and the strong tendency of their blood cells to agglutinate, instruments will not recognize single cells (Semrau et al., 2010). Should the situation arise, it is recommended to ascertain only hemoglobin values automatically (after lysis of cells), total numbers of erythrocytes, packed cell volume and erythrocyte indices in contrast should be determined manually.

Only few sources provide reference values for blood counts for the lesser chevrotains; they are listed in table 11 (where necessary values were converted to SI – units). The list does not claim to be complete, yet it shows that different authors have ascertained enormously differing values, above all for the RBC. The last row presents values collected from lesser chevrotains kept in European zoos (Semrau et al., 2010). Further reference values can be found in the Zoological Information Management System (ZIMS).

If the situation arises that abdominal radiographs are taken, and advice is needed for interpretation: the topographic and radiographic anatomy of the gastrointestinal tract of the lesser chevrotains is described by Richardson et al. (1988 a, b). In summary, the extremely large stomach complex fills the left and the ventral right of the abdomen, no omasum and caudodorsal blind sac exist. The reticulum usually lays cranioventrally on the left side abutting the diaphragm, the abomasal fundus caudal and ventral to the reticulum. Intestines are primarily relegated to the caudal quadrant, cranial to the pelvic aperture.

The multilobed liver is moved completely to the right side of the abdomen, abutting the diaphragm and extending for up to four vertebral body lengths beyond the last rib. The right kidney is abutting the caudate lobe of the liver, the left kidney lies adjacent but immediately caudal to it. The small, triangular spleen lies on the dorsal cranial aspect of the dorsal sac of the rumen.

Table 11. Variety of red and white blood cell counts (No.*: Number of different individuals/ Number of samples contributing to the reference value), (EEP survey, unpublished data, 2007).

Source	No.*	PCV [%]	RBC [T/l]	HB [mmol/l]	MCV [fl]	MCH [pg]	MCHC [g/dl]
Wallach and Boever (1983)	?	65 - 70	14 - 17	8.9	/	/	/
Snyder and Weathers (1977)	2 / ?	31.2	53	6.95	/	/	38
Weathers and Snyder (1977)	3 / ?	29.8	/	/	/	/	/
Fukuta et al. (1996)	5 / ?	50.2 +/- 6.7 (44 – 61)	/	/	/	/	/
Vidyadaran et al. (1979)	10 / ≥10	55.1 +/- 5.5 48 - 76	153.9 +/- 22.1 (123 – 216)	16.4 +/-0.9 (15.6 – 18.5)	3.5 +/- 0.3 (3.1 – 4.2)	1.1 +/-0.1 (0.95 – 1.24)	/
unpublished data		49 +/- 10 (29 – 64)	52.6 +/- 2.9 (53-68)	7.8 +/-1.3 (4.9 – 9.3)	12.3 +/-0.9 (11 – 13.1)	2 – 3.8	20.3 (13.1 – 28.6)
No.*		7 / 22	5 / 20	8 / 24	4 / 20	2 / 17	3 / 18

Source	No.*	WBC [G/l]	Differential counts [%]				
			Lymphocytes	Granulocytes			Monocytes
				Neutrophils	Basophils	Eosinophils	
Wallach and Boever (1983)	?	8.4 - 11	70	14 - 25	0 - 2	0 - 11	0 - 3
Vidyadaran et al. (1979)	10 / 10	8.1 +/- 2.0 (5.1 – 11.2)	70.4 +/- 3.9 (62 – 74)	21.2 +/- 3.7 (19 – 31)	0	2.5 +/- 0.9 (1.5 – 4)	5 – 6.5
unpublished data		6.1 +/- 3.0 (2.7 – 13.5)	60 +/- 14 (46 – 80)	36 +/- 13 (17 – 52)	0	0 - 6	0 - 3
No.*		10 / 36	6 / 32	6 / 32	6 / 32	6 / 32	6 / 32

Prior to transport to another institution or the introduction of new, unknown individuals into a collection it is recommended to perform a general health screening and check for potential contagious diseases.
This includes:

- A fecal screening: parasitology (direct smear and parasitology), bacterial culture (including Salmonella, Shigella, Yersinia and Campylobacter) and PCR for ParaTBC.
- Blood tests for Brucella, BVD, IBR, Blue Tongue, MCF, ParaTBC and a general screening when possible.
- Tuberculin skin test (bovine + avian PPD) with readings on 24h, 48 and 72 h.
- A health declaration, including a list of all infectious diseases found in the group of this individual in the past 5 years.

If further advice is needed the EAZA Deer TAG veterinary advisor, M. van Zijll Langhout (ARTIS Royal Zoo, Amsterdam), is available and can be contacted.

2.7. Considerations for Health and Welfare

Little is published on diseases occurring in in-situ and ex-situ living lesser chevrotains or other species of the family Tragulidae. A general overview of possible as well infectious as non-infectious diseases in chevrotains is provided by Flach (2003). Affections described in literature are outlined briefly below:

Between 1981 and 1987 van der Hage (1989) noted a repetitive occurrence of congenital cataracts in captive lesser chevrotains at ARTIS Zoo, Amsterdam; it was suspected that suboptimal levels of vitamin E in the diet were responsible. A stress-related, metabolic circumstance in captive lesser chevrotains is documented by Richardson et al. (1989); when harassed, animals went into a state of shock with rapid onset and of short duration, accompanied by severe hypoadrenocorticismus and hypoglycemia. In a retrospective study on causes of death at Zurich Zoo (Hauser et al., 1981), shock and hemolysis of unknown aetiology were often documented. In young animals, starvation and septicemia were the predominant causes of death.

Four wild caught animals, which died several weeks after capture, showed a parasitic infection with an unknown filaria ssp. Yet, the infestation did not seem to be the cause of death but were more likely the result from a carrier status of these chevrotains (Agungpriyono and Agungpriyono, 2006). Further parasitic infestation of chevrotains, giardiasis, coccidiosis and helminth parasites, are described in older volumes of the Southeast Asian Journal of Tropical Medicine and Public Health.

Potentially diet-related problems as extracted from necropsy reports and the 2007-survey on husbandry and diseases are listed in chapter 2.2, 'Feeding'.

The other affections frequently reported within the questionnaire of 2007 (n=20) include:

- Dental problems (n=9), such as abscessation, overgrowth and fractures of males' prominent canines.
- Affections of the claws (n=7), such as overgrowth, traumatic injuries and/or inflammations.
- Affections of the respiratory tract (n=4) by primary or secondary infection; classical symptoms such as dyspnoe, coughing or nasal discharge were rarely observed, but animals displayed lethargia, inappetence, a hunched back and/ or a dull hair coat and usually died shortly after onset (EEP survey, unpublished data, 2007).
- Inhalation pneumonia secondary to digestive tract (rumen) problems or after general anesthesia is quite common in this species, so all preventative measures need to be taken when a chevrotain is under general anesthesia.
- Dystocia: one report of clear contractions without any progress has been observed. A caesarian section was performed, and an abnormal position of the calf was found. Unfortunately, the female died after surgery. It is recommended to investigate the animal when contractions without any progress are observed in this species.

In view of dental affections mentioned above, a recently published study on irregular tooth wear in ruminants at Zurich Zoo and the tooth wear's potential as an important factor limiting life span of captive individuals shall be explained below; in lesser chevrotains, Jurado et al. (2008) found a significantly lower incidence of irregular tooth wear than in other browsing, grazing or intermediately feeding ruminant species, a particular life span limitation due to irregular tooth wear could not be demonstrated. However, authors state that dental diseases are an important health issue and that dental care comprising oral examination at every opportunity and preventive measures for improved oral and/ or dental health should be part of standard husbandry practices.

Dental problems can be related to the diet provided. Only two out of the twelve institutions that responded to this part of the 2023-questionnaire reported that the individuals did not have any dental problems, and none occurred in the past (n=2) (EEP survey, unpublished data, 2023).
Dental problems can occur in many ways, the different types of dental problems from the ten other institutions are listed in decreasing order (n=10): abscesses (n=8), infections (n=5), hooks (n=3), conjunctivitis (n=3) and dental plaque (n=1). At some institutions, multiple dental problems have occurred in the past, hence the high number of

answers on this part of the questionnaire (n=20) (EEP survey, unpublished data, 2023).

The body condition of individuals is related to their food intake and is also affected by dental problems, if they occur in this individual. Because chevrotains have a small subcutaneous fat reserve it is important that body conditions are observed, and changes within the individual's condition are reported. Preferably their weight is routinely taken to be able to compare them and monitor their condition. Training them to go into a box is a good way to weigh them without too much stress. None of the responding institutions reported that their chevrotains have an overall low or high fat reserve when observed and measured. All twelve responding institutions scored the body condition 'normal' when looking at the fat reserves of the animals (n=12) (EEP survey, unpublished data, 2023).

There are more common health issues besides dental problems within the European population of lesser chevrotains. The results of the 2023-survey will be listed down below with occurrence frequency:

- Pneumonia: never (n=7), occurring once (n=3), multiple times (n=2)
- Digestion problems: never (n=7), rarely (n=5)
- Eye problems: never (n=8), rarely (n=4)
- Coat problems: never (n=4), rarely (n=8)
- Hoof problems: never (n=6), rarely (n=6)

These results reveal that lesser chevrotains in European zoos rarely have common health issues occurring. Only pneumonia has occurred multiple times at two institutions.

No vaccinations are given at any institution that responded to the survey of 2023.

Medication can be administered in multiple ways, for example the medication can be mixed into the diet. Out of the 2023-questionnaire, only one institution of the twelve respondents did not indicate a medication method. The other eleven institutions' responses of medication methods are listed in decreasing order: through their diet (n=10), by injection (n=5), by dart (n=2), and through their drinking water (n=2). These methods can be utilized at the same time, for example the individual is getting an injection and will have further treatment with medication that is implemented in their diet (EEP survey, unpublished data, 2023).

Preliminary Results of a Retrospective Study on Necropsy Reports

Concepts of propagation programs for small populations require the compilation of all available information on causes of death, as it presents one item of necessary data for population analysis and future management. Lesser chevrotain mortality was summarized retrospectively, based on pathology records and death notes of 244 animals from 29 different European zoos between 1973 and 2007. Records and notes were, with slight modifications, categorized in analogy to the SPARKS (Single Population Animal Record Keeping System) by (1) circumstance of death, (2) primarily affected organ system and (3) suspected aetiology. 178 animals (77.72.29) were between one month and 11 years, 66 animals (28.21.17) were younger than 30 days at time of death. Results on circumstances and causes of death in neonates are given in chapter 2.4, results on circumstances and causes of death in juvenile, subadult and adult animals are presented in the following.

For 39% of juvenile and adult animal's pathological records did not provide information on the circumstance of death. In 34% of documented cases death occurred 'suddenly', in 10% animals were euthanized for a medical reason and in 7% an associated infection was suspected. Of relatively rare occurrence but noteworthy were deaths during anesthesia, fatal injuries from exhibit mates and death due to old age, furthermore other noteworthy circumstances of death were death during parturition, drowning and suffocation. Based on the fact that more than a third of documented deaths occurred 'suddenly', close observation of the group and monitoring for symptomatic animals seems to be required.

As one can expect the most affected organ systems were the respiratory and digestive tract, followed by mainly traumatic injuries of skin and musculoskeletal system. In 14% of documented cases the primarily infected organ system could not be identified. 'Generalized' comprises cases such as intoxication, drowning, or malignant growths.

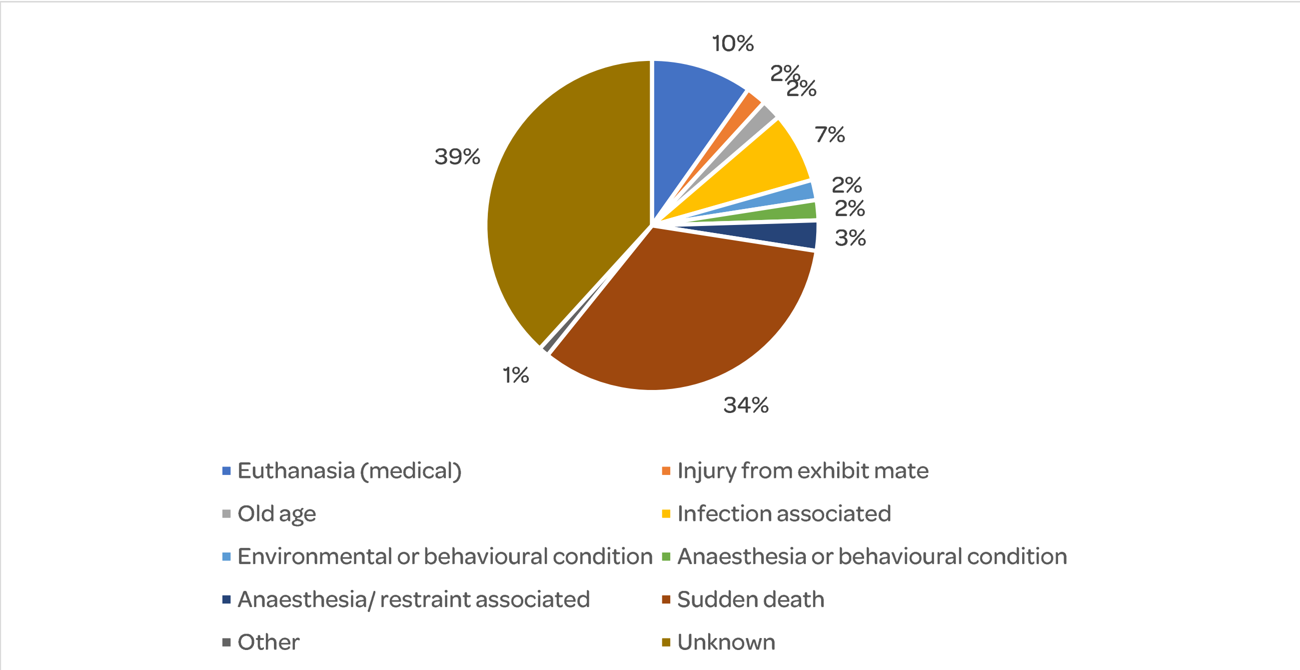


Figure 44. Circumstances of death, (EEP survey, unpublished data, 2007).

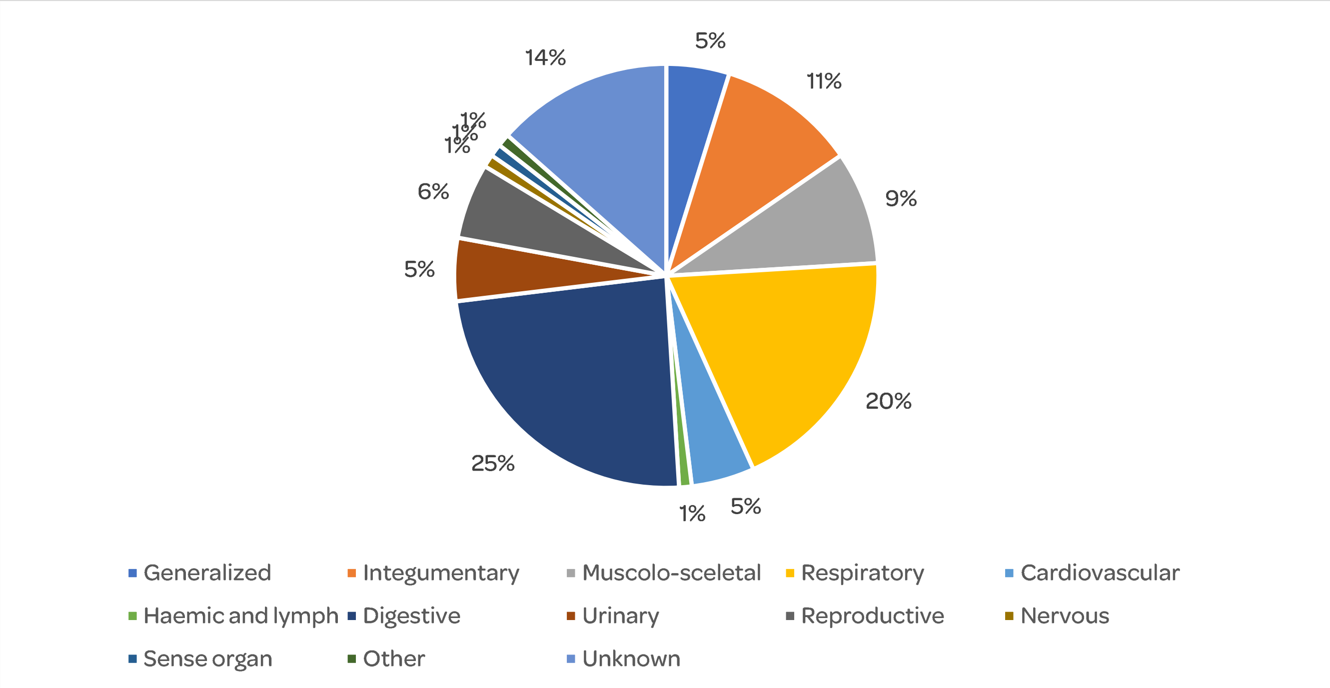


Figure 45. Topography, (EEP survey, unpublished data, 2007).

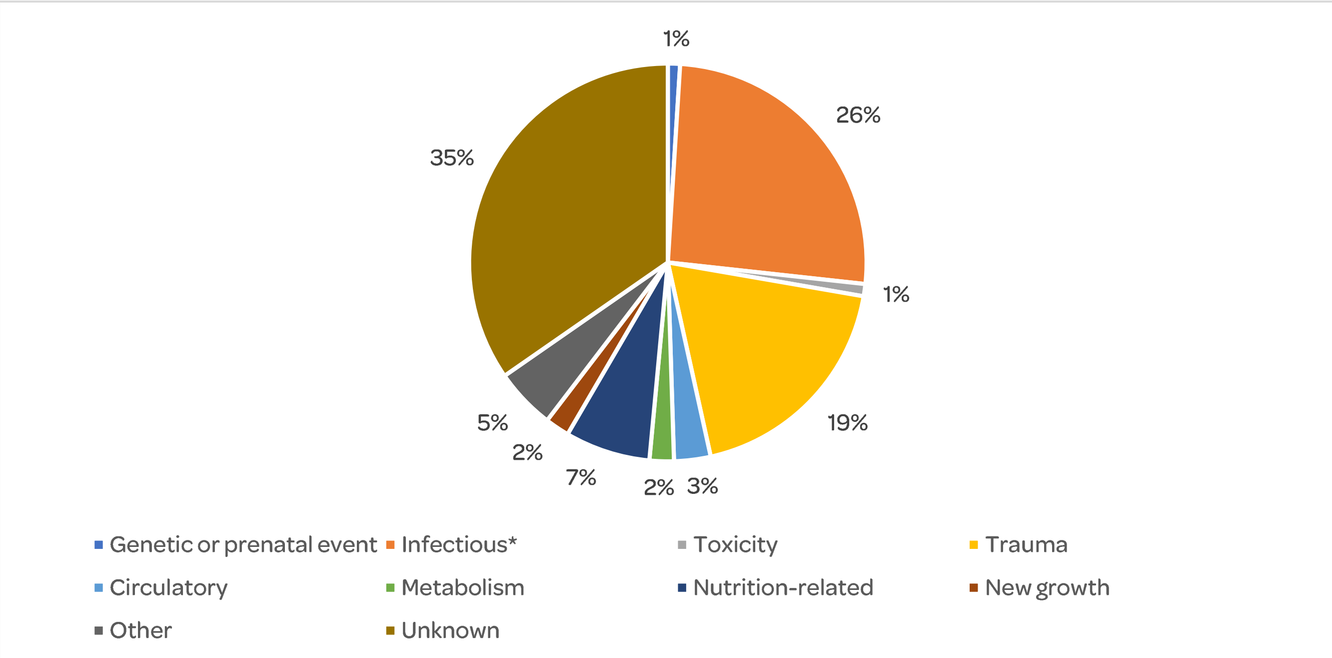


Figure 46. Aetiology, bacterial, fungal, metazoan, PPLO, protothecal, protozoan, rickettsial or viral, (EEP survey, unpublished data, 2007).

For 35% of deaths in juvenile and adult animals the aetiology was not evident, 26% were diagnosed or suspected to be the result of a primary or secondary (bacterial) infection. Nineteen percent of deaths were likely to be caused by trauma, and 7% potentially diet related. Primary circulatory failure, metabolic disorders, new growths, suffocation, drowning, etc. were rather rare events, but summarized made up about 12% of deaths in juvenile and adult animals.

Bovine Viral Diarrhea Virus in lesser chevrotains

Between 2002 and 2003 ten clinically healthy lesser chevrotains (6.4) were diagnosed to be persistently infected with bovine viral diarrhea virus (BVDV) and a 100 % vertical transmission of the pathogenic agent was seen (Grøndahl et al., 2003 a and b; Hoyer et al., 2003, 2005; Uttenthal et al., 2005, 2006). In Amsterdam Zoo and Copenhagen Zoo, two breeding females, two juvenile females and four males had to be euthanized; two more persistently infected males were excluded from the breeding program. Culled and excluded animals represented 13.2% of the total population at that time (10 out of the 76), and the total number of animals dropped from 76 to 59 between 2002 and 2003 (EEP Annual Reports). In total 15 individuals, related by bloodline or direct contact, were tested at that time. Chevrotains kept in contact to persistently infected animals had antibodies to BVDV but were virus negative. Another breeding couple was euthanized in 2004, due to a BVD-virus positive result. To date another 13 chevrotains tested in 8 different institutions were virus negative, only one animal turned out to be seropositive.

It is unlikely that captive lesser chevrotains come in direct contact with species which usually carry BVDV like cattle, sheep, bison, deer, etc. However, Uttenthal et al. (2006) hypothesized that the virus was introduced to the population by indirect infection of a pregnant female. The disease's possible impact on reproduction and general health of the lesser chevrotain population in European zoos is obscure, but secretions and excretions of persistently infected animals contained continuously significant amounts of virus (Hoyer et al., 2003, Semrau et al., 2008). It has to be noted that transmission between susceptible species is possible by direct as well as through indirect contact.

Avoidance of movements of persistently infected animals and dams carrying such fetuses is strongly emphasized by the EU thematic network on BVDV control as one item of eradication programs. To prevent a new introduction of BVDV to the captive population of lesser chevrotains as well as to the epidemiological unit 'zoo', a policy of quarantine and testing should be followed. This recommendation is in accordance with the EU-wide attempts for the eradication of BVDV. From an epidemiological point of view each susceptible animal should be tested for BVDV-antibodies and BVD-viral-genome and/ or -antigen. Depending on aim and method whole blood-, serum-, skin-, buffy coat- and/ or organ-samples may serve as specimen for laboratory diagnosis.

If further advice is needed the EAZA Deer TAG veterinary advisor, M. van Zijll Langhout (ARTIS Royal Zoo, Amsterdam), is available and can be contacted.

2.8. Recommended Research

Further research should be especially directed at the following topics:

- Determining the effects of inbreeding on the captive lesser chevrotain population.
- The question of what lineage(s) are housed and bred in European zoos; the impact of hybridization on the current population as well as strategies for future management should be discussed and investigated.
- More insight into the dietary requirements of captive lesser chevrotains and into relationships between nutrient intakes and reproductive performance, digestive function, and disease processes are needed.
- Further analysis of necropsy reports, giving more insight into the distribution and aetiology of disease processes in captive lesser chevrotains is needed.
- It would still be interesting to get to know whether there are essential differences in reproductive performance, activity, health status, etc. between chevrotains kept in nocturnal houses and those, which are kept in a diurnal set-up (Govers and van den Bergh, 1998). However, as described in this Best Practice Guidelines there are currently no lesser chevrotains kept in a diurnal set-up. If a holder would like to start keeping this species in a diurnal set-up, please contact the EEP coordinator for advice.
- Referring to the decreasing total number of chevrotains in European zoos, extension of knowledge about needs of neonates and development of reliable hand-rearing protocols seems to be required.
- The influence of different types of enrichment on lesser chevrotain welfare.
- Further collection of reliable reference values is recommended.

Appeal

Please submit published, anecdotal and experimental findings related to lesser chevrotain husbandry and health to the EEP coordinator or veterinary advisor. Gathering information is key to expand the knowledge on the husbandry and diseases of this species ex-situ. The EEP coordinator and veterinary advisor will work to disseminate findings to all institutes that house lesser chevrotains. Thank you in advance for your cooperation and kind efforts!

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Section IV Appendix

Appendix I Plant species list used in lesser chevrotain enclosures (EEP survey, unpublished data, 2023) (n=13)

FAMILY NAME	SCIENTIFIC NAME	INSTITUTION THAT HOLDS THE SPECIES
APOCYNACEAE	*Plumeria* spp.	1
ARACEAE	*Aglaonema*	1
	Anthurium andreanum	13
	Anthurium Clarinervium	13
	Anthurium hookeri	13
	Anthurium "Jungle King"	13
	Dieffenbachia	13
	Scindapsus pictus	6
	Spathiphyllum wallisii	1
ARALIACEAE	*Schefflera arboricola*	6
ARAUCARIACEAE	*Araucaria heterophylla*	13
ARECACEAE	*Chamaedorea elegans*	1
	Chamaerops spp.	3
	Kentia spp.	13
	Kentia Howea Forsteriana	13
	Philodendron "Red Congo"	13
	Philodendron selloum	13
	Phoenix canariensis	3
	Rhapis humilis	13
ASPARAGACEAE	*Aspidistra elatior*	1
	Ophiopogon spp.	13
	Yucca color guard	3
	Yucca filamentosa	3
ASPLENIACEAE	*Asplenium nidus*	6
BROMELIACEAE	*Bromelia* spp.	13
	Guzmania	13
EUPHORBIACEAE	*Codiaeum variegatum*	1
	Euphorbia geroldii	13
HIBISCEAE	*Hibiscus* spp.	1
MARANTACEAE	*Maranta leuconeura erythrophylla*	13
MORACEAE	*Artocarpus heterophyllus*	13
	Ficus Altissima	13
	Ficus Amstel King	13
	Ficus Amstel Queen	13
	Ficus Audrey	13
	Ficus bengalensis	13
	Ficus benjamina	1
	Ficus compacta	13
	Ficus cyathistipula	1
	Ficus Cytation	13

	Ficus elastica	13
	Ficus fabiole	13
	Ficus longifolia alii	1
	Ficus lyrata	13
	Ficus macroglossa	13
	Ficus microcarpa	13
	Ficus microlepia	13
	Ficus Milady	13
	Ficus Panda	13
	Ficus Papaya	13
	Ficus pumila	6
	Ficus robusta	13
	Ficus roxburghii	13
	Ficus triangularis	13
	Ficus Velvet	6
ORCHIDACEAE	*Coelogyne* spp.	6
VITACEAE	*Leea rubra*	6
ZINGIBERACEAE	*Hedychium* spp.	6

Appendix II Examples of combinations in mixed species exhibits (EEP survey, unpublished data, 2023)

INSTITUTION	ENCLOSURE SIZE (~M²)	LESSER CHEVROTAIN COMBINED WITH:
1	86	Channel-billed cuckoo (*Scythrops novaehollandiae*), Amazonian motmot (*Momotus momota*), Trumpet manucode (*Phonygammus keraudrenii*), Palawan peacock-pheasant (*Polyplectron napoleonis*), Greater blue-eared starling (L*amprotornis chalybaeus*), Mindanao bleeding-heart (*Gallicolumba crinigera*)
2	48	Galah (*Eolophus roseicapilla*)
3	50	Sulawesi bear cuscus (*Ailurops ursinus*)
4	30+ 30+	Binturong (*Arctictis binturong*) Temminck's tragopan (*Tragopan temminckii*)
6	21	Crested partridge (*Rollulus rouloul*), White-rumped shama (*Copsychus malabaricus*), Red-whiskered bubul (Pycnonotus jocosus), Java sparrow (*Padda oryzivora*), Superb fruit dove (*Ptilinopus superbus*), Mindanao bleeding-heart (*Gallicolumba crinigera*)
7	1353	Carolina duck (*Aix sponsa*), Freckled duck (*Stictonetta naevosa*), Spotted whistling duck (*Dendrocygna guttata*), Red-crested turaco (*Turaco erythrolophus*), White-cheeked turaco (*Turaco leucotis*), White-crested turaco (*Turaco leucolophus*), Livingstone's turaco (*Turaco livingstonii*), Hartlaub's turaco (*Turaco hartlaubi*), Western crowned pigeon (*Goura cristata*), Sclater's crowned pigeon (*Goura sclaterii*), Island imperial pigeon (*Ducula pistrinaria*), Pied imperial pigeon (*Ducula bicolor*), Pink-necked green pigeon (*Trenon vernans griseicapilla*), Maranon pigeon (*Patagioenas oenops*), Zebra dove (*Geopelia striata*), Dusky turtle dove (*Streptopelia lugens*), Eclectus parrot (*Electus roratus*), Chaco chachalaca (*Ortanis canicollis*), Bali myna (*Leucopsar rothschildi*), Red-billed blue magpie (*Urocissa erythrorhyncha*), Java sparrow (*Lonchura oryzivora/Padda oryzivora*) White-faced saki (*Pithecia Pithecia*), Finlayson's squirrel (*Callosciurus finlaysonii*), Prevost's squirrel (*Callosciurus prevostii*), Linnaeus's two-toed sloth (*Choloepus didactylus*), Large flying fox (*Pteropus vampyrus*) Green basilisk (*Basiliscus plumifrons*)
10	276 33	White-naped pheasant-pigeon (*Otidiphaps aruensis*), Crested partridge (*Rollulus rouloul*), Mindanao lorikeet (*Trichoglossus johnstoniae*), Blue-crowned laughingthrush (*Pterorhinus courtoisi*), White-rumped shama (*Kittacincla malabarica/Copsychus malabaricus*), Red-whiskered bubul (*Pycnonotus jocosus*), Spangled cotinga (*Cotinga cayana*), Cuban grassquit (*Tiaris canora*), Blue-black grassquit (*Volatinia jacarina*) Red-footed tortoise (*Chelonoidis carbonarius*), Amboina box turtle (*Cuora amboinensis*), Chinese box turtle (*Cuora flavomarginata*) Order of butterflies and moths (Lepidoptera)
11	100	Red-crested turaco (*Turaco erythrolophus*), Crested partridge (*Rollulus rouloul*), Bali myna (*Leucopsar rothschildi*) Goeldi's marmoset (*Callimico goeldii*), Emperor tamarin (*Saguinus imperator*), Chinese pondturtle (*Mauremys reevesii*) Solomons

		island skink (*Corucia zebrata*)
12	1800	Bird species (UNK)
13	31	White-faced saki (*Pithecia Pithecia*)
	16 & 8	Goeldi's marmoset (*Callimico goeldii*)
14	16	None
15	146	Muntjac/barking deer (*Muntiacus muntjac*)
		Aldabra giant tortoise (*Aldabrachelys gigantea*)
16	15	Crested partridge (*Rollulus rouloul*)
		Pygmy slow loris (*Nycticebus pygmaeus*), Lyles flying fox (*Pteropus lylei*)

Appendix III Example of a currently used lesser chevrotain diet at ARTIS Amsterdam Royal Zoo

ARTIS Amsterdam Royal Zoo – Animal Feeding Programme
Kantjil

Species information	Photo
Common name (ENG); Java mouse-deer **Common name (NL);** Kleine kantjil ***Scientific name;*** *Tragulus javanicus* **Habitat;** From Southern China throughout South East Asia. Forests with low vegetation, often close to water. **Natural diet:** Herbivore and folivore, eating leaves, buds, shrubs and fruits. In zoos mouse-deer also eat an occasional insect, chicks or eggs from ground breeding birds and invertebrates. **Body Weight ≅ : 1,5-2 kg**	

Diet per day per; adult (estimated)

PRODUCT	AMOUNT	INFO
Leafeater pellet (small DK zoological®)	30-50g	
Horse muesli (equiral®)	Tablespoon	Mixed with pellets
Rabbit or Guinea pig pellet	30-50g	
Vegetables chopped into 10-20mm parts and mixed (carrot, bok choy, celery, beet, zucchini, paprika, broccoli, green peas (Canned), etc.) Leafy vegetables (endive, Brussel sprouts, Spinach)	Eaten within 30-60 minutes	After pellet feeding
In spring and summer fresh herbs, flowers and browse from Artis gardens.	Unlimited	In the afternoon
Fruit (apple, papaya, berries, tomato, paprika, melon, grapes)	10% of total fresh food offered	
General multivitamin-mineral supplement	Est. 2 x per week	

Preparation & Remarks	Presentation
▪ Pellets are offered first thing in the morning.	▪ In food trays
▪ Leafy Vegetables fed completely (not chopped)	▪ Occasionally scattered or hidden
▪ Grapes and peas used for rewarding during target training or crate training	▪

Enrichment	General remarks
▪ Minimum of 3 feedings per day	▪ Adapt the diet and amount of food to circumstances (pregnancy, growth, winter-summer, overall activity etc.)
▪ Occasional boiled quail egg or insects (not always taken) or tofu	▪
▪ Scattered St. Johns bread	▪
▪ They can eat some plant material in their enclosure (mainly ficus spp)	▪
▪ Feed fresh herbs, flowers and plants from Artis gardens if available	▪

Date-version; 6-2020
Approved for distribution; Frank Verstappen

ARTIS AMSTERDAM ROYAL ZOO