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Gundis (*Ctenodactylus gundi* (Rothmann, 1776)) in European Zoos
Since when, how to keep, and why?

Gundis (*Ctenodactylus gundi* (Rothmann, 1776)) in europäischen Zoos
Seit wann, wie zu halten und warum?

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Summary

Gundis (*Ctenodactylus gundi*) are small herbivorous and philopatrous (females) rodents that live in colonies in arid and semiarid climates of North Africa. They are not endangered, but are rarely kept in zoos. In 1995 and later in 2007 a small "founder group" of gundis came from Tunisia to the "Aquazoo Löbbecke Museum" (Düsseldorf, Germany). The two groups originated from widely separated areas of Tunisia and formed the initial base of Gundis kept in European zoos. However, all gundis kept in European zoos as part of the studbook (ESB) to date are descendants of the animals from 2007. An over 20 years' experience in these animals as well as data from a studbook kept since the year 2000 by one of us (Sandra Honigs) allow describing husbandry and breeding guidelines, trends of the population currently kept in zoos and pay attention to some non or insufficiently explored matters concerning gundi biology. According to previous experience, gundis cannot be kept in human care in the long term without major effort. They are preferably kept in groups in enclosures with a floor space of at least 1.5 m x 1 m x 1.2 m (W x D x H) for one pair; per animal the area increases by half a square meter each. The substrate should consist of clay and a thin layer of sand. In addition, the enclosure must contain rock structures with hiding places, be well air-conditioned and have at least one place

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for “sunbathing”. Feeding is done with a mixture of various seeds and conventional rabbit food. The data so far from the Aquazoo and the studbook show that it is very difficult to form new breeding pairs or breeding groups with individuals from different populations because of the high aggression towards foreign conspecifics. Females are fertile for at least six years giving birth to one to four young per litter. The mortality of the young is relatively high and the number of births seems to be decreasing in some institutions probably due to inbreeding depression**.** However, some individuals lived almost ten years.

Key words: Gundis (*Ctenodactylus*), studbook, keeping and breeding

Introduction

Gundis (Ctenodactylidae) are small, approximately guinea pig-sized, territorial herbivorous rodents living in social groups. They are obligate rock-dwellers that live up to an elevation of about 2.300 m (*Ctenodactylus* sp.) in semi-desert and desert mountainous areas of north and east equatorial Africa (Fig. 1, left and right; summarized in Gouat, P., 2013 and López-Antoñanzas, 2016), with low precipitation (about 50 to 300 mm per year), mean temperatures of 2 to 7°C in the coldest month, and mean temperatures near their home range of 27 to 35°C (data from Tunisia, Séguignes, 1983).

Ctenodactylidae might be one of the oldest rodent families which are united in the suborder Ctenohystrica together with the Hystricognathi (porcupine-like rodents) (e.g., Huchon et al., 2000, 2002, 2007; Upham & Patterson, 2012), originated in East Asia during the Eocene and then spread to Africa (e. g., López-Antoñanzas, 2016; López-Antoñanzas et al., 2011). Currently, four genera with five species are known, i.e. *Pectinator spekei*, *Massoutiera mzabi*, *Felovia vae*, and two *Ctenodactylus* species (*C. gundi* and *C. vali*). The range of *C. gundi* extends from Morocco over Algeria and Tunisia to Libya, that of *C. vali,* is restricted to relatively small and isolated areas in Algeria, Morocco and Libya (see general maps in Cassola, 2022). In Algeria, the ranges of the two species are immediately adjacent but do not overlap (Gouat, P., 1988).

Name-giving for the whole family are ‘combs’ of strong hairs present on the 1st and 2nd toes (= 2nd and 3rd “finger”) of the hind feet, which serve for grooming (Fig. 2, left). The rest of the coat is very fine and dense and serves mainly the insulation for cold and perhaps also protects against UV radiation (Fig. 2, right; George, 1978a).

Fig. 1: Left: Detail from the habitat of *Ctenodactylus gundi* in Bou-Hedma National Park (Tunisia). Right: Gundi in its natural habitat. Photos: S. Honigs

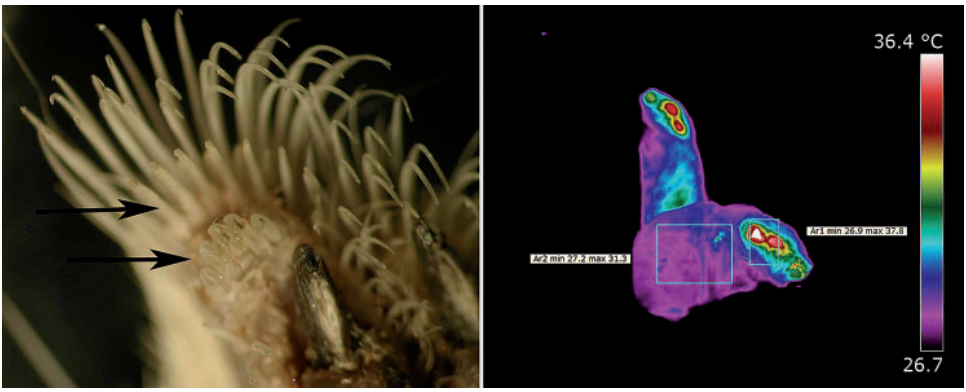

Fig. 2: Left: The typical combs over the claws of the first and second toe of the hind feet (see arrows). Right: Thermography of two gundis (ambient temperature about 25°C). Note the insulating effect of the fur (colour towards blue). Photos: S. Honigs

The two *Ctenodactylus* species are very similar. Diagnostic characters include a greater length of head and body, higher mean weight and more hairs per cm² of skin in *C. gundi,* different 'alert' calls, and the shape of the last molar (M3) in the maxilla, which is L-shaped in *C. gundi* and kidney-shaped in *C. vali* (see George, 1978a; 1982; summarized in Gouat, P., 2013 and López-Antoñanzas, 2016).

Probably the most common species of *Ctenodactylus* observed in the field and held in human care is *C. gundi*, to which we largely confine our discussion below. *C. vali* we consider only occasionally; many of the findings so far only on this species may also apply to *C. gundi*.

In the natural habitat, gundis have a large number of enemies, primarily snakes, but also dogs, jackals, hawks, and ravens; in addition, they are also hunted and eaten by humans (e. g., Gouat, P., 2013) and are still taken from the field in larger numbers as research animals, e. g. to study their potential role as reservoir host of *Leishmania tropica* (Bousslimi et al., 2012) or to explore the evolutionary history of paramyxoviruses (Ghawar et al., 2018). According to the IUCN Red List, both *Ctenodactylus* species are rather not threatened (Read List Category, *C. gundi*: "least concern", Cassola, 2022; *C. vali*: "data deficient", Gerrie et al., 2016).

The numerous publications on the biology of gundis, which appeared in rapid succession from about 1973 onwards, report on field observations, but also on studies of animals in human care (containing detailed information on reproduction and specific behaviour, the study of which is hardly possible in the field) and on museum material (Gouat, P., 2013; López-Antoñanzas, 2016).

In Germany gundis have been kept in human care already at the end of the 19th century – but not very successfully. Brehm (1880) was able to keep them alive for only 14 days. P. Matschie (1895), head of the mammal department of the Zoological Museum in Berlin, presented gundis in a popular magazine at that time and also illustrated them (Fig. 3).

The Austrian biologist Paul Kammerer (1880-1926) cared for and carefully observed a pair of gundis for a time as a student (Kammerer, 1902). At the beginning of the 20th century, the zoologist and explorer Paul Spatz (1865-1942) brought living gundis to the zoological gardens of Berlin and Frankfurt, where they did "quite well there for a while" (sie „…hielten sich da eine Zeitlang ganz gut…" Brehm, 1922, p. 204). After that, gundis found their way into various museums and research institutions from time to time. The Hubrecht Laboratory in Utrecht (Holland) possessed about 300 (!) preserved uteri of animals collected in 1912 and 1913 (de Lange, 1934). Roth (1956), Biological Station Wilhelminenberg, Vienna (Austria), kept a specimen

Fig. 3: Early drawing of *Ctenodactylus gundi* (from P. Matschie, 1895).

from Tunisia and Eisentraut (1977), Museum Alexander Koenig, Bonn (Germany), maintained some individuals that were a souvenir of a research trip to Tunisia (Africa). However, rearing of the young was not successful. Grenot (1973) reported on two successful breedings of *C. vali*, emphasizes the rapid weight gain and the different weight development of twins, but omits information on husbandry.

Occasionally, gundis from the pet trade or from some zoos end up with private individuals, from whom, however, little is learned about keeping and breeding successes. As far as we know, apart from the early attempts mentioned above, gundis were not kept in European zoos for a longer period of time until the end of the 20th century.

In the years 1995 and 2007 gundis (*Ctenodactylus gundi*) from Tunisia were brought to the Aquazoo Löbbecke Museum Düsseldorf (NRW, Germany) – hereafter referred to as Aquazoo – reproduced there and were distributed over numerous European zoos.

The Aquazoo still keeps gundis today and thus has many years of experience in handling these animals as well as in their care and breeding. This experience of more than 25 years as well as data from the studbook kept by the first author since 2000 allow us to formulate guidelines for the keeping and breeding of these animals, to draw attention to some not or only insufficiently investigated questions of their biology and to show trends in the populations maintained until today (see also Honigs et al., 2002; Honigs & Greven, 2003). Concerning the vast literature, we mainly consider in the following those studies, which are zoo-relevant and from which also guidelines for an adequate husbandry of these animals can be derived.

Origin of the gundis in European Zoos and the European Studbook

In 1995, five adult gundis (three males and two females; hereafter referred to as population A) arrived from the Bou-Hedma National Park (Tunisia) to the Aquazoo, where in cooperation with the “Deutsche Gesellschaft für Technische Zusammenarbeit GmbH (GTZ)” a permanent

exhibition for the information center of this park was prepared. We assumed that the gundis belonged to a social group (see below), especially since the animals arrived almost unharmed in a single transport crate. For several years, all gundis kept in European zoos descended from these five "founder animals". The last individual from this population (from F4) was born on 12.06.2012 and died at the Aquazoo on 20.03.2017 at the age of almost five years.

On 20 April 2007, in cooperation with 'Erlebnis Zoo Hannover, Germany' 14 gundis (six males, eight females; hereafter referred to as population B) arrived at Aquazoo Löbbecke Museum from Parc Nationale de Dghoumès, Tunisia (approx. 170 km southwest of Bou-Hedma; national park since 1980). Of the 14 individuals, nine were adults (four males, five females), three were adolescents (one male, two females), and two (one male, one female) were only a few weeks old. The animals were housed in two transport crates. Again, we assumed that the animals were from a single social group and that the few fatalities recorded during and after transport were largely stress-related. Of the imported animals, five specimens died in Düsseldorf already in the same year, three further specimens died in 2008, leaving only a few animals for breeding.

The individuals of the two populations could be distinguished by their habitus (size, skull shape, ear shape, etc., Fig. 4). However, both were clearly *C. gundi* (Honigs et al., unpub.). The original idea to mate gundis from population B with gundis from population A for blood refreshment failed because of the aggressiveness of the animals against group strangers (see below) and the fact that after two successful matings the young were born dead, so that animals from the two populations (until the extinction of population A) were kept separately.

Fig. 4: Habitus of *C. gundi*. Left: Female from Bou-Hedma (Population A). Right: Female from Dghoumès (Population B). Note the differences concerning the head, the shape of the ear and the fur. Photos: S. Honigs

In 2000, a monitoring studbook (MSB) for gundis was initiated by Aquazoo Düsseldorf in the framework of the Small Mammal Taxon Advisory Group of the European Association of Zoos and Aquaria (EAZA), which was converted into an ESB (European Studbook) in 2009 and has been maintained by Sandra Honigs (Aquazoo Löbbecke Museum) since 2000. Animals from private keeping or from keeping for research purposes are not recorded in it. Because of the striking differences, the animals from populations A and B were kept separately from each other and also kept separately in the studbook, until the final extinction of group A.

The documentation of the development of population A in human care until 1999 is incomplete. The five founder animals from population A were all deceased by 2000. Which of the five individuals were actually involved in the production of offspring is unknown. Some of the offspring were subsequently assigned studbook numbers G00001 through G00090. The "founder animals" remained at the Aquazoo; the offspring were given to various zoos. The animals from Bou-Hedma always reproduced only moderately, so that only rarely more than 50 individuals

existed at the same time in the zoos participating in the breeding program. Until the extinction of the population in F 4, a total of 69 births were recorded.

All imported gundis from population B and their offspring received the studbook numbers consecutively starting with G00091. Due to failures during transport or shortly after arrival in Düsseldorf – caused by bite injuries, diarrhea, parasite infestation etc. – finally only five animals (two males, three females) with the numbers G00095, G00096, G00099, G00101 and G00102 were suitable for breeding. All animals were fitted with a transponder chip between the shoulder blades.

As part of the breeding program, a varying number of zoological gardens in Europe have kept gundis over the past 20 years. Currently, 16 zoological gardens in Europe hold a total of about 100 individuals (as of September 2023). A total of 363 transfers occurred between the participating keepers during this time; 157 of these were through the Aquazoo. This was due to the fact that individual animals were taken back from the Aquazoo and attempts were made here to socialize them with new partners (see below). If successful, these new groups were then transferred to other zoos. The gundis currently kept in European zoos under the breeding program are exclusively offspring of the founder animals from population B.

Husbandry

In the field gundis live territorially and in relatively stable social groups. Females in particular are philopatric, i.e. relatively site-related (e.g., George, 1974; Gouat, P., 1991 a, 2013; Gouat, J. & Gouat, P., 1984; Gouat, P. & Gouat, J., 1983; Nutt, 2005). The social structure of these groups (= distinct reproductive units) varies and can be characterised with the keywords ‘family groups’, ‘multiple females per male’, ‘multifamily groups’, ‘ cooperative breeding units’ (e. g., Nutt, 2007b). Accordingly, information on the group size of a colony varies (two to 11, possibly even up to 20 individuals). This is also true for the area of the common home range (= territory), which the individual groups colonise, actively mark and defend against conspecific intruders (e. g., George, 1974; Gouat, J. & Gouat, P., 1984; Nutt, 2005; summary in Gouat, P., 2013).

Group size and territory in the field are strongly influenced by food availability, climate and altitude, and fluctuate throughout the year and between different years (Gouat, J. & Gouat, P., 1984). In extreme cases, for example in desert habitats on the edge of the Sahara, social units are composed of only one breeding pair (Gouat, J. & Gouat, P., 1984; Seguignes & Vernet, 1996). These dependencies apparently also shape the different breeding patterns or social structures within a group ranging from facultative monogamy, unimale polygyny (the most common association) to multi-male polygyny (Nutt, 2005, 2007 a, b). From the information about the habitat and living in the field it can be deduced how a gundi enclosure should look like and that adult gundis can be kept in pairs with offspring or several (one or up to three males, several females and offspring), but not how large a gundi enclosure should be at least.

More precise information about the very early keeping of gundis, e.g. in the Frankfurt Zoo (see above), no longer exists (J. Köhler, in litt.). Later, gundis were kept in human care (see above) and then either in pairs in cages (e.g. Kammerer, 1902; floor space of the cage 50 cm x 50 cm) or individually (Roth, 1956; floor space 2 m x 2 m), but altogether not for a very long time. Eisentraut (1977) kept up to five specimens in a cage with a floor space of 2 m x 1 m, recorded three births, but could only keep his animals alive for a maximum of eight months. Studies, for which successful keeping and breeding of gundis over longer periods were preconditions, appeared from 1973 (see citations below) and contain more or less continuous observations often over several years (for all species of the Ctenodactylidae except *Felovia* and *Pectinator*) as well as data on enclosure size (cage area 150 cm x 150 cm with up to five individuals for *C. gundi*: George, 1978b; cage area 2 m x 2.25 m with four individuals: Gouat, J., 1985).

Housing

According to the expert opinion on the minimum requirements for keeping mammals of the German Federal Ministry of Food and Agriculture (2014), a pair of gundis should have a minimum area of 1.5 m² (minimum height 1.2 m) and for each additional animal 0.5 m² area more. This may be fine in principle, but we are of the opinion that also considering animal welfare, gundis should be kept in (family) groups in more spacious enclosures with near-natural equipment.

In the years from 1995 to the present day, groups of gundis of various sizes (from one pair to a maximum of eight males together with five females) have been kept and bred in the Aquazoo Löbbecke Museum in the large exhibition enclosure, as well as backstage in smal-

Fig. 5: Various enclosures for gundis at Aquazoo Löbbecke Museum. Top: Exhibition enclosure. Below left: Gundis at the cave entrance. Below right: Backstage housing. Photos: S. Honigs

Fig. 6: Enclosures for gundis in the exhibition at other zoos. Top left: Korkeasaari Zoo, Helsinki (photo: Korkesaan Zoo, Helsinki, Finland, 2012). Top right: Former gundi enclosure at Magdeburg Zoo. Photo: Magdeburg Zoo, K. Ruske, 2017.

ler enclosures. The enclosure in the exhibition provides a floor area of about 8 m^2; the floor consists of a clay layer with a thin overlay of fine-grained sand in which the gundis frequently bathe (dust baths), a behaviour that very likely reduces the fur lipids as e.g. in gerbils and chinchillas (see Thiessen & Pendergrass, 1985; Barber & Thompson, 1990). In the background are superstructures of natural stone, e.g., granite or sandstone (which is preferable because gundis often gnaw on stones), with niches and burrows of various sizes (Fig. 5, top), one of which is large enough to accommodate the entire group (Fig. 5, below left). This is important for group cohesion and also applies to the burrows visited by gundis in the field (see also Gouat, P., 1991).

The show enclosure is illuminated all year round with PC-controlled LED spotlights ("basic lighting"), which are switched on successively over a period of 1 h from 6:30 am and from 5:30 pm to 6:30 pm. In addition, there are heat radiators (SolarRaptor; 8:00 am to 5:00 pm; through these up to 40°C are reached on the stone surface) and UV radiators (Osram Ultra Vitalux 300W, 11:00-12:00 am) above the areas where the animals mainly stay. The enclosure receives additional daylight through a glass roof. The temperature above the floor is about 25°C during the day and drops to about 20°C at night; on the stone wall it varies between 21°C and a maximum of 31°C. This is also true for the sleeping caves, i.e. the large climatic fluctuations that gundis can be exposed to depending on their natural environment (see above) are not taken into account when keeping them. Humidity varies from 24.5 to 73.3% during the day. Two food bowls, a drinking water container and mineral stones ("Nagerstein". Fa. Dehner, Rain) complete the equipment. Feeding takes place daily between 8:00 and 10:00 am. The cleaning of the enclosure is mainly limited to the removal of sand too soaked with urine and fecal pellets, which can be found (also in the field) in the rocky area and especially in front of the burrows (George, 1974; Gouat, P., 1992).

Behind the scenes, individual animals or pairs (in the larger terrariums sometimes up to nine individuals for a short time were kept in containers with base areas ranging from 100 cm x 50 cm to 160 cm x 60 cm (the heights varied between 100 and 120 cm). Here, too, the substrate consisted of sand (Rhine sand and a corner with fine chinchilla sand); in addition, there were hiding places between stones. Temperature, light conditions and humidity largely corresponded to the conditions in the show enclosure (Fig. 5, below right). A survey of the zoos involved in the breeding programme revealed that the animals are mainly kept in relatively large exhibition enclosures under largely similar conditions (cf. Fig. 6).

Nutrition and feeding

In their natural habitat gundis forage over long distances eating leaves, stalks, flowers and seed of almost any plant, i.e. they are opportunistic and generalistic herbivores adapted to utilise a fibrous and low fat diet (e.g., George, 1974; Gouat, P. & Gouat, J., 1983; Gouat, P., 2013). Recent studies show that, depending on the seasons, the animals consume mainly the green parts of a wide range of perennial and annual plants and their fruits (Lasgaa et al., 2021). Gundis pick up food directly by mouth from the ground or from a food bowl, but they are also able to fix larger pieces of food with their forepaws on the substrate to eat from or even, contrary to earlier views (George, 1982), to hold these pieces with the forepaws and guide them to the mouth (Fig. 7).

Fig. 7: Gundi feeding directly from the food bowl (left) and with the help of the front paws (right). Photos: S. Honigs

The gundis at the Aquazoo Löbbecke Museum have been fed a well-established diet (8 to 10 g per adult animal per day; see Honigs et al., 2002) consisting of the following ingredients (given as approximate proportions): 6% wheats; 6% rye; 6% carob; 6% millet; 2% mung beans; 12% sesame; 6% oat flakes; 12% paddy rice; 12% dried lentils; 12% grass seeds plus 20% pellets for guinea pigs or rabbits. Occasionally, hay is offered. Fresh feed (including husk leaves of corn cobs, bark of blackberry bushes and willow) is also provided. Food with high fat content (peanuts, sunflower seeds) should be fed, if at all, only moderately, because gundis tend to put on fat quickly. Gundis also like to eat fresh herbs such as thyme and basil. In view of the analyses of Lasgaa et al. (2021), the diet of gundis should be adapted to even more natural conditions and increase the proportion of grasses and shrubs.

Food containing free sugars (such as fruits, raisins, breakfast cereal etc.) result in diarrhea. Although not studied in detail, we assume that the insulin of gundis, as in other hystricomorphic rodents, is much less physiologically active than the insulin of other mammals (e.g. Opazo et al., 2004, 2005).

Gundis meet their fluid requirements through food and probably through metabolic processes. However, the concentration ability of their kidneys does not seem to be sufficient to survive a prolonged period with little or no water (*Ctenodactylus vali*: Rouffignac et al., 1981; George, 1987). Perhaps the relatively long (expressed as a percentage of total length of the gut) large intestine compared to other desert rodents reabsorbs water, especially since the animals' feces are also very dry (Gouat, P., 1993, 2013). However, gundis in human care should definitely have access to a watering trough, which they use, even if only occasionally, on the diet given above.

Handling and Sexing

Gundis are extremely shy in the wild, but quickly become accustomed to human observation in the show enclosure. Only when you enter the enclosure they disappear into their hiding places. Sometimes (for physical examination or medical treatment) it is necessary to catch gundis. In larger enclosures this is possible when the animals have retreated into a crevice. These should be large enough to reach into with the hand. The gundis are carefully (the hairs come out easily) grabbed by the back, pulled out of the burrow and brought into a slightly inclined position (belly up). Held in this way, they are usually quiet and can be easily examined (Fig. 8, top right). When grabbed by the neck, the animals resist violently and usually lose hair at this point. Since they can be held easily and without resistance in other ways, the neck grip should be avoided. Despite the sharp claws, it is also not advisable to use gloves in which you either have too little feeling (thick leather gloves) or in which the animals get caught when kicking (cotton gloves). Nets are also not recommended because the claws get caught in any form of mesh.

Also for sex determination one must take the animals in the hand. Younger males and probably subdominant males do not have a well-developed scrotum. Testicles are located lateral to the penis that can be pushed out by pressure with two fingers on either side. The anogenital distance of the male is approximately twice the size of that of the female. The vagina of the female is open only during parturition and estrus. The females have four teats. One pair is located at the

Fig. 8: Top left: Gundi shortly after birth. Top right: Holding a gundi for closer inspection. Bottom left: Genital regions of a female. Bottom right: Genital region of a male. Photos: S. Honigs

level of the clavicles in front of the base of the forelegs, another pair is located laterally behind each arm (George, 1978b).

Notes on behaviour

Activity

The activity of gundis depends strongly on the ambient temperature. In the wild gundis appear to be diurnal with activity peaks early in the morning and afternoon (before sunset). They leave their shared hiding places at sunrise, forage, rest in the shade or in a hiding place during the hottest part of the day to avoid temperatures above 32°C (Gouat, P., 1991b), but also spend a considerable time of the day sunbathing (up to 50% of the day, cf. Gouat, P. & Gouat, J., 1987; Gouat, P., 1991b) and are active again in the afternoon (before sunset) (George, 1974; Gouat, P., 1991b, 2013; Gouat, P. & Gouat, J., 1983; Nutt, 2005). At temperatures below 10°C and above 35°C, gundis remain in their hiding places. They are most active at temperatures between 25°C and 30°C (George, 1974, 1977). In gundis in human care there is a clearer distinction between sunbathing periods and other resting periods (the animals then lie on stones etc. and no longer under the radiant heater). The corresponding values vary greatly (perhaps this also has something to do with the social position within the group, but individual animals spent almost 70% of the day with both rest periods (Honigs et al., 2002)). When relatively cool ambient temperatures (around 20°C) persist for several days, gundis feel visibly uncomfortable and erect their hairs (Fig. 12A). However, we could always observe nocturnal activities at such temperatures both in the exhibition enclosure and backstage (Honigs et al., in prep.).

Social behaviour

Gundis communicate with each other using a rich accoustic repertoire and drumming (George, 1981; Gouat, J. et al., 1985). In general, members of a gundi group appear to interact relatively peacefully in the field. In case of quarrels, they also have enough space to avoid each other or to leave the group permanently. The territory is defended against intruders and marked with feces (especially at the entrances to the hiding places), urine and probably also with secretions of the anal gland (Gouat, P., 1991). This can also be observed in human care. To our knowledge, nothing is known about hierarchies in wild family groups. Young sexually mature males are expelled from the family group at different times depending on the stocking density.

In human care, depending on enclosure, group size and composition, males may remain in the family. Housing multiple males in a family group does not necessarily result in increased aggression between males. Nevertheless, sometimes quarrels like barking, chasing, and banditing and even serious mutual injuries can be observed (females seem to be more aggressive than males). Quarrels between males, females, and females and males often start without apparent cause and end with biting attacks. As weaker individuals flee but are still pursued in some cases, bite wounds are increasingly found in the posterior body region. According to our observations, there seems to be a linear hierarchy in larger groups of males and females, which is apparently visible during allo-grooming (Fig. 9, top left) and during joint sunbathing (Fig. 9, top right) – here the animals often lie in close proximity next to each other or on top of each other. Dominant individuals are preened more or are preferred as neighbours during joint sunbathing. Males and females that have been classified as dominant often greeted each other very intensively when they met by sniffing each other and mutual grooming; the dominant male grooms the dominant female conspicuously often (Honigs et. al., 2002).

Fig. 9: Social behaviour of gundis in a group. Left: Allo-grooming. Right: Sun-bathing. Photos: S. Honigs

The importance of common sunbathing is also evident from the fact that the animals become restless and also quarrel more often if they cannot do this. Quarrels also occur when the group cannot find refuge together in a cave, or when the enclosure is cleaned too much and all droppings are removed. Finding a common sleeping cave is essential for the cohesion of the group. The size of the caves varies depending on the size of the group. It should be approximately 15 cm x 16 cm x 15 cm (D x W x H) for three specimens. Inside the cave, the animals huddle close together and remain in the typical resting position (cf. Fig. 9).

Quarrels can lead to individual animals being excluded from the group and even killed. Injured animals should be quickly removed from the group and, if possible, separated together with a less aggressive conspecific from the same group (the sex is not decisive in this case). It should be noted, however, that even a short-term separation (about two days) can lead to them no longer being accepted by the group. If integration does not succeed (see below), the animal in question must be separated from the group and may even have to be kept alone for the rest of its life. The place required for this should be planned for when keeping gundis.

Establishing new breeding groups

The high aggressiveness towards foreign or "alienated" individuals makes it difficult to maintain stable and thus perhaps long-term healthy breeding groups in human care. The incorporation of previously isolated animals or new individuals into existing groups or the creation of new pairs from different groups must be done slowly and intensively monitored.

In this regard, the literature (e.g., summary in Quesenberry & Carpenter, 2012) recommends various procedures for rodents (rats, mice, chinchillas), including placing the animals together in sufficiently large enclosures with numerous hiding places and distraction opportunities, exaggerating their own odour with strong-smelling substances (e.g. camphor), or even "coerced closeness," i.e. placing the animals together for a period of time in a cage so small that they cannot fight and then placing them in a larger container container with hiding places etc. For gundis, most of these procedures have not proven successful.

In the Aquazoo Löbbecke Museum we could successfully socialise single or several (up to four) gundis with other conspecifics in many cases: For this purpose, the future partners were each placed in one half of an established enclosure divided by a grid. After about two days they changed sites. This procedure was repeated about three times. During this time the enclosure should not be cleaned. After that, the animals were lightly rubbed with the sand from both halves of the enclosure, then placed together under supervision in one part of the enclosure, and then observed for another three days. Sometimes it is necessary to repeat this

procedure. The decisive factor is the age of the animals to be integrated and how long the individual animals had already lived alone.

It has not been possible to integrate young animals that were still dependent on (substitute) milk during hand rearing into a group, but has been successful in individual cases at a later date.

Reproductive behaviour and breeding

Seasonality

In the field, reproduction is seasonal but occurs in different months depending on climatic conditions. George (1978b) suggested that the young she found in Tunisia in March were born in January to March and that gundis may generally be opportunistic breeders that could reproduce at any time if environmental conditions permitted. J. Gouat (1985) recorded births in the field in February to March and in May (see also Meddour et al., 2019). Table 1 summarises the breeding success in twelve relatively regular breeding institutions (studbook data). A total of 374 births were recorded from 2007 to 2022. The preference of a certain season can not necessarily be deduced from this.

The apparently climate-dependent seasonality of reproduction described for the field does not seem to exist in captive gundis under the above-mentioned largely stable conditions, which are largely constant throughout the year, or at least cannot be read from these data. It is clear, however, that under these conditions gundis can give birth to young in any month. Repeatedly, females have also given birth several times (up to a maximum of three times) in one year.

Tab. 1: Number and distribution of births and number of newborns during the year from July 2007 to December 2022 (data from twelve institutions that more or less regularly breed gundis).

Jahr	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	**Total**
2007	0	0	0	0	0	0	0	0	0	0	1	1	2
2008	0	1	0	0	0	1	0	0	1	1	0	0	4
2009	0	1	0	0	3	0	1	0	2	0	1	0	8
2010	1	3	1	1	3	0	2	1	1	5	2	0	20
2011	2	3	3	4	4	4	3	5	5	1	6	2	42
2012	2	6	4	3	7	2	4	1	2	3	3	3	40
2013	0	6	3	2	6	1	3	2	4	3	3	1	34
2014	1	1	5	5	1	4	1	6	2	2	3	2	33
2015	4	5	7	4	4	4	1	1	2	4	3	1	40
2016	3	5	2	9	4	2	0	4	2	4	1	2	38
2017	4	3	6	9	4	1	6	3	1	5	2	1	45
2018	5	3	3	2	2	2	1	1	2	2	1	4	28
2019	0	1	7	1	1	2	2	1	0	1	0	1	17
2020	1	0	2	0	0	1	0	2	1	1	2	0	10
2021	0	0	0	0	0	1	0	0	1	0	2	0	4
2022	1	2	0	1	0	0	1	0	1	2	1	0	9
Total	24	40	43	41	39	25	25	27	27	34	31	18	**374**

Mating, gestation, and birth

In the field, reproduction begins with the exclusion of supernumerary young males by both the non-reproducing the reproducing females (Nutt, 2005; Gouat, P., 2013). The most detailed data on the reproduction of *C. gundi* comes from J. Gouat (1985) and P. Gouat & J. Gouat (1987), who observed gundis in human care, but also in the field. These authors describe how males approaching the female, specific sexual trills, mounting and copulation that involves multiple thrusting intromissions. We have also repeatedly observed brief copulation attempts with probably non-responsive females (which have not become pregnant afterwards). Even such females are not conspicuously aggressive against the males harassing them. The latter also do not show submissive postures while approaching the female. However, it often happens that males ready to mate try to hold the female by biting the posterior region of the body. At most, the female loses fur; these bites never lead to serious injuries.

The females have regular oestrous cycles. The known data on this and on the gestation period are from George (1978b) and J. Gouat (1985) – own data are not available – and differ in some respect (data by George are given in brackets): The vagina is open 7.4 (4.7) days and closed 24.7 (23.6) days per cycle. The entire oestrous cycle is about 26 to 35 days (mean 28.7), the seasonal anoestrous 103-367 days (George, 1978b). The gestation period lasts 69-79 days. The few own observations lie approximately in this range. The number of young is reported to be one to three; twin births are most common (Gouat, J., 1985).

The data on the number of newborns per birth can be largely confirmed on the basis of 473 births (total number of births from 2007 to 2022 recorded in the studbook). In the period from 2007 to 2022, a total of 165 single young were born, 198 times twins, 90 times triplets and 19 times even quadruplets. With a private owner a female gave birth even to five young, three of which died immediately after birth; the other two could be raised by the mother until sexual maturity (H. Künzel, pers. comm.). In the field, triplets are already exceedingly rare (Gouat, J., 1985). Quadruplets in the field have been reported only once to our knowledge (Kock & Schomber, 1960). The birth weights varied from 16 to 40 g and are of course also dependent on the number of young per litter (Gouat, J., 1985; see also Honigs et al., 2002).

Rearing

Gundi young are precocious, fully furred with teeth and open eyes. They are able to walk within one hour after birth. They are sunbathing already a few hours after their birth. Very careful studies are already available on the rearing of the young and their behaviour, for example on the typical vocalisations of the young, which can be heard especially in the first two weeks, e.g., when they approach the mother, on the behaviour during suckling as well as the motor development of the young (George, 1978b; Gouat, J., 1985; Gouat, J. & Gouat, P., 1987; Gouat, P. & Gouat, J., 1987; Gouat, J. et al., 1985).

The newborns are licked dry by the group members (both sexes) (Honigs et al., 2002) and in the first days of life are guarded by the mother and probably by the dominant male, but also warmed and protected by the other adults. When adults approach the young, the young raises its tail and makes chirping sounds. The adults then groom the young and lick its genital region.

The mother begins to suckle her young about 12 h after birth for the first time. In the first week, especially in the morning hours shortly after the light came out, they suckled in intervals of about 20 min. The process takes less than 4 min each time. From the age of one week the young move safely and climb nimbly in the rocks. The mother then suckles the young about once an hour. According to our observations, the young are suckled more often in the morning and afternoon hours. There is often a break over the midday period. Allonursing – rare in human

care according to J. Gouat & P. Gouat (1987), but never seen in the wild – was observed regularly. Young gundis like to lie across an adult for rest. The mother defends her offspring against co-inhabitants (the gundis were for a time associated with panther turtles and spiny tails) by hissing and biting. The young are grabbed by the nape of the neck and carried to safety; they typically stretch strongly and remain in this position until they are set down again (Fig. 10, top left).

Fig. 10: Top left: Typical neck bite of the mother. Top right: Suckling of a young gundi. Bottom left: Mouth to mouth contact of mother and infant. Bottom right: Mouth-to-mouth contact of two adults. Photos: S. Honigs

The young are suckled up to six weeks (Fig. 10, top right), but according to our observations often even longer, but start to eat solid food (dry food mix and vegetables) already three days after birth. According to Gouat, P. (2013), young animals already ingest vegetable material long before weaning at about two weeks of age.

The significance of the conspicuous and frequent mouth-to-mouth contact between young and adults is not clear (Fig. 10, bottom left). We observed that the young start mouth-to-mouth contact at an age of about two to three days and also "chirp". According to George (1978b) food should be given to the young during this process, but according to J. Gouat, & P. Gouat (1987) only water.

Such contacts also occur between adults (Fig. 10, bottom right). Mouth-to-mouth contacts between mother and youngster are also known from other rodent species as "mouthing" or "mouth licking" (see Ewer, 1968). In *Acomys* this is thought to transfer food preferences (McFadyen-Ketchum & Porter, 1989), in *Micromys minutus* food (regurgitation feeding: Ishikawa & Mori, 1998). In *Meriones unguiculatus*, this contact – saliva-related chemical communication – is not limited to mother and child, but affects different phases of social life (Block et al., 1981).

Gundis gain weight particularly rapidly in the first weeks after birth, the mean weight gain from birth (day 0) to day 28 was about 2 g per day. The adult weight (about 290 g) is reached after about 70 days. Weaning usually occurs after 6 to 8 weeks (George 1978b). Figure 11 shows the nearly linear weight development of three juveniles (two littermates raised within a group, one hand-raised specimen). The littermates were marked with animal colour spray immediately after birth and then captured and weighed at irregular intervals (see also Honigs et al., 2002).

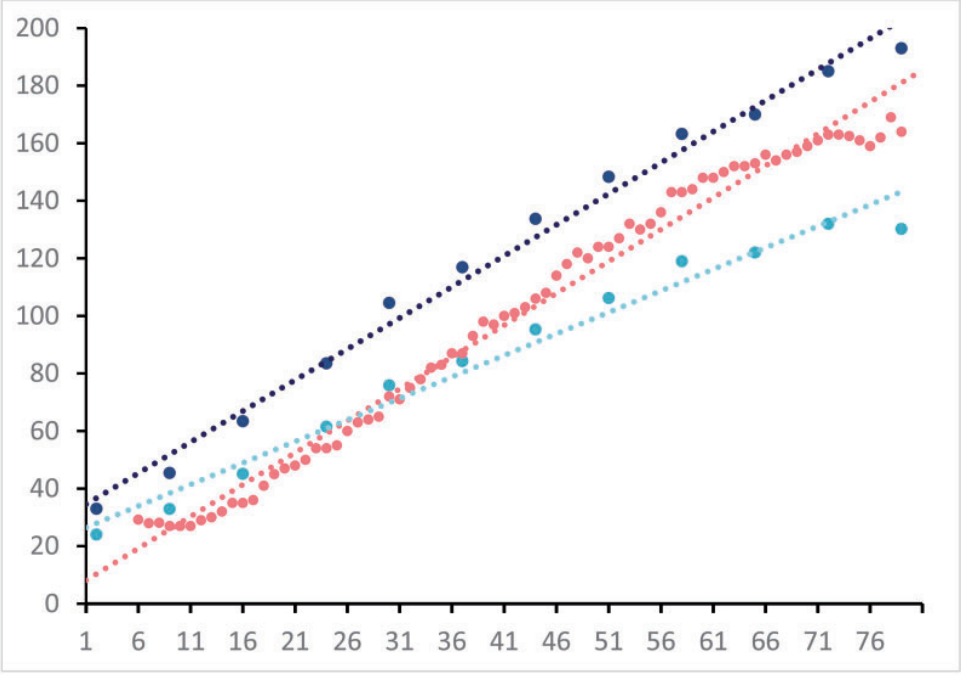

Fig. 11: Weight development of three gundis from birth to about days 79 and 104. Blue circles: Litter mates. Red circles: Hand-raised young.

Twins or triplets grow differently; often one of the newborns is heavier. Weaning is normally at six to eight weeks. *C. gundi* is fully grown and sexually mature in nine to twelve months George (1978b). These observations can be largely confirmed from our data (Fig. 11). However, we observed that some of the females were sexually mature at about six months. Young gundis have a lighter coat than adults until about six months of age.

Young that have lost their mother in an established group are often raised by other lactating females. Hand-rearing is possible, but very time-consuming. In the Aquazoo Löbbecke Museum, the young were given a hand-warm nutrient liquid consisting of 50 ml warm water, one teaspoon of Aptamil Pre (Milupa), one teaspoon each of cat milk powder (Fa. Gimpet) and baby fruit mash (e.g. apple, carrot, etc., from Fa. Hipp), a pinch of Mulgatol Junior (vitamin preparation, containing mainly vitamines B1, B2, B6, C and E, niacin, pantothenic acid and biotin) and Bene-Bac Gel (Albrecht GmbH) as well as half a teaspoon of herbicare plus (WDT) or Critical Care, Herbivore (Oxbow). The mixture is administered with a syringe (2 ml syringe with silicone teat, opening width 1 mm). During the first three weeks, the young must be fed every three hours during the day and every three to four hours at night; later it is enough to feed

every three hours during the day. Initially, about 1-2 ml were taken up per feeding. Hand-fed animals show a delayed weight development (Fig. 11; see also *C. vali*: George, 1978b, without further details).

In a total of seven trials, two newborns were successfully raised to sexual maturity. Even after 50 days, neither had reached the weight of naturally reared young. The two hand-reared young were successfully integrated into an existing group. One of these animals reached an age of 6.2 years, the other 7.4 years.

Life span

The life span of gundis in the wild is unknown. According to previous authors, gundis in human care either died relatively early (see above) or the authors only indicate over which periods they kept gundis without saying anything about the life span of single individuals (e. g., George, 1978a, b; Gouat, J., 1985). In the Aquazoo Löbbecke Museum, individual gundis have sometimes become almost 10 years old. However, to give a mean lifespan seems not very meaningful in view of the high mortality rate of the juveniles. Birth and death data (mostly without information about the cause of death) from the studbook of 102 gundis from population A show a mean age of 1.73 ± 2.2 years (range 0 to 8.96). If only the 46 individuals older than one year are taken into account, the corresponding values are: 3.62 ± 2.07 (range 0 to 7.96). The corresponding data of 692 gundis from population B reached an average age of 1.58 ± 2.2 years (range 0 to 9.69). Of these, 305 individuals become older than one year (3.42 ± 1.81; range 0 to 8.69). Of the 387 animals that died in the first year of life, 78 (approx. 20%) were stillborn or did not survive the first day. A total (including stillborns) of approx. 50% (341 animals) died before the first year of life. This high juvenile mortality is obviously not due to a possible inbreeding depression (see below), because it was already observed in the imported animals from the beginning.

Diseases

In the field, gundis are infested with various ectoparasites (fleas, mites, lice, and ticks), with a marked prevalence in males and old individuals; their abundance is closely related to climatic conditions (Meddour et al., 2022); wild-caught gundis also harbor tapeworms (e.g., Eisentraut, 1977). They are also reservoir hosts of *Leishmania* species (Bousslimi et al., 2012; Ghawar et al., 2018) and paramyxoviruses (Ghawar et al., 2017).

Gundis, like other rodents in human care, are at risk of numerous infections. The most common health problems are diseases of the respiratory system and the gastrointestinal tract. The routes of infection are mostly unknown and treatment of visibly ill animals has been largely limited to treatment of symptoms. Many of these may also have contributed to the high mortality of the young (see above).

Sick gundis often have a shaggy and dull coat and/or sunken flanks (Fig. 12, top right). In case of severe indisposition, the neck and back hairs are erected (Fig. 12, top left). In general, the animals should be carefully observed and frequently taken in hand to check e.g. eyes, nostrils and genital region and to be able to treat bite injuries, which occur mainly during the mating season or in rank fights. Wounds usually heal without complications, but large bite marks (Fig. 12, middle left) must be treated. In some males, inguinal hernias occurred especially in the third and fourth year of life (Fig. 12, bottom left), some of which could be successfully operated under anesthesia.

The operated gundis could be returned to their group without problems within the first two days. Sometimes purulent inflammations of the sole of the feet were observed (Fig. 12, middle right).

Diagnoses of diseases of gundis by veterinary diagnostic institutions are of varying informative value as exemplified by 110 deceased gundis (see Tab. 2). Of these, 47 gundis (52%) were affected by multiple diseases. In 19 animals (17%) the examination remained inconclusive.

Fig. 12: Symptoms of disease and injuries in gundis. Top left: Raised back hair. Top right: Shaggy hair and sunken flanks. Middle left: Bitten off ear. Middle right: Inflamed sole of feet. Bottom left: Inguinal hernia in a male. Bottom right: Tumor in the neck region. Photos: S. Honigs

In the Aquazoo Löbbecke Museum, the following pathogens with serious consequences for the gundi groups kept here have been detected post mortem (p. m) and/or in the living animal (liv.) and the feces (collective sample of droppings).

Salmonella (liv., droppings, p. m.). Symptoms: Acute chronic diarrhea, especially in young animals. Mortality was high, especially of new born and young animals. The animals were not medically treated, but the entire group was isolated until the death of all individuals.

Tab. 2: Disease problems of 110 gundis diagnosed post mortem by various veterinary diagnostic institutes.

Organ system	
digestive tract	enteritis (16), diarrhea (1), endoparasites (oxyurans, coccidians) (3), fatty liver (2), liver carcinoma (3), gastritis (1), malnutrition (12)
integument	purulent inflammation of feet (4), umbilicitis (2), leucosis (1), anasarca (1), tumor (1), dermatitis (1), mastitis (1)
reproductive	endometritis (2), inflammation of the vulva (2), abdominal pregnancy (1)
respiratory	(bacterial) pneumonia (25), peribronchitis (2), pulmonary edema (2), lung tumor, (1), pasteurellosis (1), tapeworm infestation of the lung (1), dust in the lung (2), undeveloped lung of fetuses at birth (3), amniotic fluid aspiration (fetus) (1)
urinary	nephropathy (3), glomerulosclerosis (1), fatty kidney (1), hepatitis (7), kidney disease (2), glomerulosclerosis (1), urethritis (1)
varia	lymphatic hypoplasia (1), cacheixa (due to oxyurans (1), chondrodysplasia (1), tuberculosis (23), tumors in various organs (4), cardiovascular failure (4), severe bite wounds (9), sepsis (4), heart defect (1), degenerative liver disease (1), abdominal bacterial infection (1), liver disease (1), middle ear infection (1), broken ribs (1)

Various *Mycobacterium* species, some of which occur together, including *M. avium, M. kansasii* (p. m.). Symptoms: Weight loss, coughing, sneezing, runny nose. Due to the risk of transmission (also to humans), the entire group has been euthanised in the event of positive detection.

Giardia (droppings, p. m.). Symptoms: Diarrhea (however, does not apply to all rodents; see Wasson, 2007). In general, gundis infected with *Giardia* (of different "strains" identified by ELISA -Tests plus PCR) are no longer kept in other zoos as a precaution. Since treatments (against diarrhoea) failed in the Aquazoo Löbbecke Museum, the sick animals were kept separated by sex until death.

Isolation from conspecifics that may be necessary for sick animals – if possible, treatment in the established group is to be preferred – should be as short as possible (see above), otherwise, if the disease permits, they should be socialised with a compatible social partner from their group.

It is remarkable that under the mentioned housing conditions neither in the Aquazoo Löbbecke Museum nor in other zoos serious dental diseases have ever occurred so far, which can be quite frequent in many rodents because of their continuously erupting teeth (see Quesenberry & Carpenter, 2012).

Why gundis in zoos?

Gundis are not an endangered species. So why should they be kept in zoological gardens? A first survey of zoological gardens keeping gundis has shown that these animals are main-

ly shown for "educational purposes". They look cute (Lorenz's child scheme), are apparently active during the day and at night, and are easily visible even when they are resting during the day, so overall they are attractive to a wide range of visitors. Gundis also represent inhabitants of deserts and semi-deserts, which can be used to demonstrate adaptations to these extreme biotopes. Less frequently, attention is drawn to the fact that this is a phylogenetically very old group of animals. In addition, observation of captive gundis can contribute significantly to knowledge of, for example, their behaviour, which is nearly impossible to observe in all details in the field.

Conclusions and prospects

Gundis can be kept in zoological gardens for long periods of time in an animal-friendly manner. Doing the same is attracting more and more interest. For example, in June 2019, the Aquazoo Löbbecke Museum shipped nine animals from European zoos to Japan (Saitama Children's Zoo, Higashimatsuyama, Saitama Prefecture). However, the current population is at risk, given the small number of founder animals and possible resulting inbreeding depression, and the fact that, at least in human care, it is extremely difficult and costly to acclimate animals that are not part of a group to each other. Even though gundis are not an endangered species and replenishment from the wild should be possible, their continued existence in zoos also depends on a sound breeding strategy and cooperation among participating zoos. In particular, there would be a need for optimisation with regard to the investigation and reporting of causes of death, the inclusion of more precise, probably then also more expensive, diagnostic possibilities, a regulated exchange of animals and compliance with a certain standard in the housing and nutrition of the animals. This would certainly also help to reduce the high mortality rate of young animals.

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Zusammenfassung

Gundis (*Ctenodactylus gundi*) sind kleine herbivore und philopatrische (Weibchen) Nager, die in kleinen Kolonien in ariden und semiariden Gebieten Nordafrikas leben. Sie sind nicht bedroht, werden aber dennoch nur selten in Zoos gehalten. In den Jahren 1995 und 2007 kam jeweils eine kleine „Gründergruppe" aus weit voneinander entfernten Gebieten Tunesiens in den „Aquazoo Löbbecke Museum", Düsseldorf, welche die Ausgangsbasis aller in europäischen Zoos gehaltenen Gundis bildeten. Alle heute in europäischen Zoos gehaltenen und im

Zuchtbuch geführten Gundis sind jedoch Nachkommen der Tiere aus 2007. Eine über 25-jährige Erfahrung mit diesen Tieren sowie Daten aus einem seit dem Jahr 2000 von Sandra Honigs geführten Zuchtbuch erlauben es, Haltungs- und Zuchtrichtlinien sowie Trends der derzeit in Zoos gehaltenen Population zu beschreiben und einige nicht oder nur unzureichend erforschte Aspekte der Gundi-Biologie zu berücksichtigen. Nach den bisherigen Erfahrungen sind Gundis in menschlicher Obhut langfristig nicht ohne größeren Aufwand zu halten. Sie werden möglichst in Gruppen in Gehegen ab einer Grundfläche von mindestens 1,5 m x 1 m x 1,2 m (B x T x H) für ein Paar gehalten; pro Tier erhöht sich die Fläche um je einen halben Quadratmeter. Der Bodengrund sollte aus Lehm und einer dünnen Schicht Sand bestehen. Außerdem muss das Gehege Felsaufbauten mit Verstecken enthalten, gut klimatisiert sein und mindestens einen Platz zum „Sonnenbaden" besitzen. Gefüttert wird mit einem Gemisch aus verschiedenen Sämereien und herkömmlichem Kaninchenfutter. Die bisherigen Daten aus dem Aquazoo Löbbecke Museum und dem Zuchtbuch zeigen, dass es wegen der hohen Aggression gegenüber fremden Artgenossen sehr schwierig ist, mit Individuen aus verschiedenen Populationen neue Zuchtpaare oder Zuchtgruppen zu bilden. Die Weibchen sind mindestens sechs Jahre fertil und bringen pro Geburt ein bis vier Junge zur Welt. Die Sterblichkeit der Jungen ist nach wie vor relativ hoch. Einzelne Individuen wurden jedoch fast zehn Jahre alt. Die Geburtenrate scheint in den letzten Jahren möglicherweise aufgrund von Inzuchtdepression abzunehmen.

References

Barber, N., & Thompson, R.L. (1990). Sandbathing reduces fur lipids of chinchillas, *Chinchilla lanigera*. Animal Behaviour, 39, 403-405.

Block, M.L., Volke, L.C., & Hayes, M.J. (1981). Saliva as a chemical cue in the development of social behaviour. Science, 211, 1062-1064.

Bousslimi, N., Ben-Ayed, S., Ben-Abda, I., Aoun, K., & Bouratbine, A. (2012). Natural infection of North African gundi (*Ctenodactylus gundi*) by *Leishmania tropica* in the focus of Cutaneous Leishmaniasis, Southeast Tunisia. The American Journal of Tropical Medicine and Hygiene, 86(6), 962-965.

Brehm, A.E. (1880). Brehms Thierleben. Allgemeine Kunde des Thierreichs. 2. Auflage, Erste Abtheilung – Säugethiere. 2. Band. Leipzig: Verlag des Bibliographischen Instituts.

Brehm, A. (1922). Brehms Tierleben. Allgemeine Kunde des Tierreichs. 4. Auflage. Säugetiere 2. Bd. (herausgegeben von O. zur Strassen, neubearbeitet von L. Heck & M. Hilzheimer). Leipzig: Bibliographisches Institut.

Bundesministerium für Ernährung und Landwirtschaft (BMEL) Tierschutzreferat (2014). Gutachten über Mindestanforderungen an die Haltung von Säugetieren. Berlin, Stand. 7. Mai 2014, pp. 143-144. Available fromhttps.//www.bmel.de/SharedDocs/Downloads/DE/_Tiere/Tierschutz/HaltungSaeugetiere.pdf?__blob=publicationFile&v=8.

Cassola, F. (2022). *Ctenodactylus gundi.* The IUCN Red List of Threatened Species 2022. e.T5792A22191625. https.//dx.doi.org/10.2305/IUCN.UK.2022-2.RLTS.T5792A22191625.en. Accessed on 13 September 2023.

De Lange, D. (1934). Beobachtungen an puerperalen und schwangeren Uteri von *Ctenodactylus gundi*. Zeitschrift für mikroskopisch-anatomische Forschung, 36, 488-496.

Eisentraut, M. (1977). Gefangenschaftsbeobachtungen am Gundi (*Ctenodactylus gundi*). Bonner Zoologische Beiträge, 28, 33-40.

Ewer, R.F. (1968). Ethology of mammals. New York: Plenum Press New York.

George, W. (1974). Notes on the ecology of gundis (F. Ctenodactylidae). Symposia of the Zoological Society of London, 34, 143-160.

George, W. (1978a). Combs, fur and coat care related to habitat in the Ctenodactylidae (Rodentia). Zeitschrift für Säugetierkunde, 43, 143-155.

George, W. (1978b). Reproduction in female gundis (Rodentia. Ctenodactylidae). Journal of Zoology London, 185, 57-71.

George, W. (1981). Species-typical calls in the Ctenodactylidae (Rodentia). Journal of Zoology London, 195, 39-52.

George, W. (1982). *Ctenodactylus* (Ctenodactylidae): one species or two? Mammalia, 46, 375-380.

Gerrie, R., & Kennerley, R. (2016). *Ctenodactylus vali* (errata version published in 2017). The IUCN Red List of Threatened Species 2016, e.T5793A115518270. Available from https.//dx.doi.org/10.2305/IUCN.UK.2016-3.RLTS.T5793A102029922.en. Accessed on 13 September 2023.

Ghawar, W., Pascalis, H., Bettaieb, J., Mélade, J., Gharbi, A., Snoussi, M.A., Laouini, D., Steven, M., Goodman, M., Ben Salah, A., & Dellagi, K. (2017). Insight into the global evolution of Rodentia associated *Morbilli-related* paramyxoviruses. Scientific Reports, 7, 1974.

Ghawar, W., Bettaieb, J., Salem, S., Snoussi, M.-A., Jaouadi, K., Yazidi, R., & Ben-Salah, A. (2018). Natural infection of *Ctenodactylus gundi* by *Leishmania major* in Tunisia. Acta Tropica, 177, 89-93.

Gouat, J., & Gouat, P. (1984). Répartition et habitat des goundis en Algérie (Rongeurs, Cténodacylidés). Mammalia, 48, 227-238.

Gouat, J. (1985). Notes sur la reproduction on *Ctenodactylus gundi* rongeur Cteonodactylidae. Zeitschrift für Säugetierkunde 50, 285-293.

Gouat, J., & Gouat, P. (1987). Le répertoire comportemental du goundi *Ctenodactylus gundi* (Rongeurs, Ctenodactylidae), II. Ontogenèse. Mammalia 51, 173-193.

Gouat, J., Coulon, J., & Gouat, P. (1985). Les émissions sonores de *Ctenodactylus gundi* (Rothman) et leur signification comportementale. Behavioural Processes, 11(3), 279-299.

Gouat, P. (1991a). Gestion communautaire (de l'espace et défense du territoire chez le goundi, *Ctenodactylus gundi*. In: M. Le Berre & L. Le Guelte (Eds), Le rongeur et l'espace, pp. 219-230. Chabaud, Paris.

Gouat, P. (1991b). Adaptation comportementale à la température chez trois espèces de Cténodactylidés sahariens. In: Leberre, M. & L. Leguelte (Eds), Le rongeur et l'espace, pp. 79-89. Lyon, R. Chabaud.

Gouat, P. (1992). Faecal pellet size differences as a field criterion to distinguish between the two *Ctenodactylus* species (Mammalia, Rodentia). Zeitschrift für Säugetierkunde, 57, 183-185.

Gouat, P. (1993). Biometrics of the digestive tract of three species of Ctenodactylidae: comparison with other rodents. Zeitschrift für Säugetierkunde, 58, 191-193.

Gouat, P. (2013). Family Ctenodactylidae. Gundis and pectinator. In: Happold, D.C.D. (Ed.), Mammals of Africa. Vol. 3., pp. 628-640. London: Bloomsburg Publishing.

Gouat, P., & Gouat, J. (1983). L'habitat du goundi (*Ctenodactylus gundi*) dans le massif de l'Aurés (Algérie). Mammalia, 47, 507-518.

Gouat, P., & Gouat, J. (1987). Le répertoire comportemental du goundi *Ctenodactylus gundi* (Rongeurs, Ctenodactylidae), I. Description. Mammalia, 51, 3-25.

Grenot, C. (1973). Sur la biologie d'un rongeur heliophile du Sahara, le «goundi» (Ctenodactylidae). Acta Tropica, 30 (3), 237-250.

Honigs, S., & Greven, H. (2003). Biology of the gundi, *Ctenodactylus gundi* (Rodentia. Ctenodactylidae), and its occurrence in Tunisia. Kaupia, Darmstädter Beiträge zur Naturgeschichte, 12, 43-55.

Honigs, S., Gettmann, W., & Greven, H. (2002). Verhaltensbeobachtungen an Gundis (*Ctenodactylus gundi* Rothmann, 1776). Zoologischer Garten N.F., 72, 68-100.

Huchon, D., Catzeflis, F.M., & Douzery, E.J.P. (2000). Variance of molecular datings, evolution of rodents and the phylogenetic affinities between Ctenodactyliae and Hystricognathi. Proceedings of The Royal Society B, 267, 393-402.

Huchon, D., Madsen, O., Sibbald, M.J.J.B., Ament, K., Stanhope, M.J., Catzeflis, F., de Jong, W., & Douzery, E.J.P. (2002). Rodent phylogeny and a timescale for the evolution of glires. Evidence from an extensive taxon sampling using three nuclear genes. Molecular Biology and Evolution, 19(7), 1053-1065.

Huchon, D., Chevret, P., Jordan, U., Kilpatrick, C.W., Ranwez, V., Jenkins, P.D. Brosius, J., & Schmitz, J. (2007). Multiple molecular evidences for a living mammalian fossil. Proceedings of the National Academy of Sciences, 104(18), 7455-7499.

Ishikawa, R., & T. Mori (1998). Regurgitation feeding of young in harvest mice, *Micromys minutus* (Rodentia. Muridae). Journal of Mammalogy, 79, 1191-1197.

Kammerer, P. (1902). Das Käfigleben des Kammfingers (*Ctenodactylus gundi*, Rothm.). Zoologischer Garten, 43, 188-193.

Kock, D., & H.W. Schomber (1960). Our days among the gundis (*Ctenodactylus gundi*). African Wildlife, 14, 199-203.

Lasgaa, F., Bounaceur, F., Baha, M., & S. Aulagnier (2021). First quantitative data on the feeding ecology of an arid zone rodent, the common gundi (*Ctenodactylus gundi*). Mammalia, 85, 551-550.

López-Antoñanzas, R. (2016). The family Ctenodactylidae. In: D. E. Wilson, Th. E. Lacher Jr., & R. A. Mittermeier (Eds), Handbook of the Mammals of the World. Vol. 6., pp. 288-299. Barcelona: Lynx.

López-Antoñanzas, R., & Knoll, F. (2011), A comprehesive phylogeny of the gundis (Ctenodactylidae, Rodentia). Journal of Systematic Paleontology 9, 379-398.

Matschie, P. (1895). Über die Haltung von Gundis. Natur und Haus, 3, 68-69.

McFadyen-Ketchum, S.A., & Porter, R.H. (1989). Transmission of food preferences in spiny mice (*Acomys cahirinus*) via nose-mouth interaction between mothers and weanlings. Behavioral Ecology and Sociobiology, 24, 59-62.

Meddour, S., Mlik, R., & Sekour, M. (2019). Caractérisation de l'abondance de Goundi d'Atlas *Ctenodactylus gundi* (Rodentia, Ctenodactylidae) dans le sud des Aurès (Est d'Algérie). Internatioanl Journal of Natural Resorces and Environment, 1, 29-35.

Meddour, S., Mlik, R., Dik, B., Hastriter, M.W., & Sekour, M. (2022). Ectoparasites of the common gundi (*Ctenodactylus gundi* Rothmann) from the Aures Region, Algeria. Annals of Parasitology, 68(3), 519-529.

Nutt, K.J. (2005). Philopatry of both sexes leads to the formation of multimale, multifemale groups in *Ctenodactylus gundi* (Rodentia. Ctenodactylidae). Journal of Mammalogy, 86, 961-968.

Nutt, K.J. (2007a). Genetic reconstruction of breeding patterns in gundis (Rodentia. Ctenodacytlidae). Behavioral Ecology and Sociobiology, 61, 1651-1663.

Nutt, K.J. (2007b). Socioecology of rock-dwelling rodents. In: J.O. Wolff & P.W. Sherman (Eds), Rodent Societies. An Ecological & Evolutionary Perspective, pp. 416-426. Chicago, Illinois: University of Chicago Press.

Opazo, J.C., Soto-Gamboa, M., & Bozinovic, F. (2004). Blood glucose concentration in caviomorph rodents. Comparative Biochemistry and Physiology. Part A Molecular and Integrative Physiology, 137(1), 57-64.

Opazo, J.C., Palma, R.E., Melo, F., & Lessa, A.P. (2005). Adaptive evolution of the insulin gene in caviomorph rodents. Molecular Biology and Evolution, 22(5), 1290-298.

Qesenberry, K.E., & Carpenter, J.W. (2012). Ferrets, rabbits, and rodents. Clinical Medicine and Surgery (3th ed.). Elsevier, St. Louis, Missouri, USA.

Roth, H. (1956). Beobachtungen am Gundi, *Ctenodactylus gundi* (Rothmann, 1776). Säugetierkundliche Mitteilungen, 4, 120-123.

Rouffignac de, C., Bankir, L., & Roinel, N. (1981). Renal function and concentrating ability in a desert rodent: the gundi (*Ctenodactylus vali*). Pflügers Archiv – European Journal of Physiology, 390, 138-144.

Séguignes, M. (1983). Approche des facteurs bioclimatiques qui régissent la distribution de *Ctenodactylus gundi* (Rodentia, Ctenodactylidae) en Tunisie. Mammalia, 47, 493-1506.

Séguignes, M., & R. Vernet (1996). Présence de *Ctenodactylus gundi* (Rodentia, Ctenodactylidae) das deux sites isoléts du sud tunesien. Mammalia, 60(1), pp. 151-153.

Thiessen, D., & Pendergrass, M. (1985). Change of pelagic lipids in the Mongolian gerbil, *Meriones unguiculatus*, as the result of autogrooming and sandliving. Journal of Mammalogy, 66, 469-475.

Upham, N.S., & Patterson, B.D. (2012). Diversification and biogeography of the Neotropical caviomorph lineage Octodontoidea (Rodentia. Hystricognathi). Molecular Phylogenetics and Evolution, 63, 417-429.

Wasson, K. (2007). Protozoa. In: J.G. Fox, S.W. Barthold, M.T. Davisson, C.E. Newcomer, F. Quimby, & A.L. Smith (Eds): The mouse in biomedical resarch. 2. Edition, pp. 518-549. London: Elsevier.