

Husbandry, feeding, veterinary aspects, pathological findings and historical survivorship of Indian (*Hystrix indica*) and African (*Hystrix cristata*) crested porcupines in European zoos

Haltung, Fütterung, veterinärmedizinische Aspekte, pathologische Befunde und historische Überlebensdaten von Indischen (*Hystrix indica*) und Afrikanischen (*Hystrix cristata*) Stachelschweinen in europäischen Zoos

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Abstract

Indian crested porcupines (*Hystrix indica*) and African crested porcupines (*Hystrix cristata*) are popular zoo animals in Europe and are kept by a total of around 400 institutions. The aim of this study was to evaluate the husbandry and feeding conditions of these two porcupine species in European zoos in more detail and to collect common disease patterns. To this aim, data were collected from 90 responding zoos. On average, 3.8 ± 2.7 porcupines were kept per enclosure, with most zoos (70%) having a combined outdoor and indoor enclosure. The average outdoor enclosure was 164 ± 196 m² in size and supplemented by an average 14 ± 18 m² indoor enclosure. The most common methods for population control were same-sex groups (39%) and a 'breed and cull' regime (28%). Medical training was practised by only 23% of the zoos. Although according to current knowledge porcupines rarely become ill under human care, there are some typical clinical

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pictures: 22% (n=10) of all clinical cases in this study were skin-related, with half of these skin pathologies being caused by intraspecies aggression. Likely due to improved husbandry conditions in recent years and advances in wildlife medicine, the overall European zoo population of both species showed an improvement in historical zoo survivorship for both adult and juvenile animals. The average estimated porcupine diet consisted of vegetables, pelleted compound feed, cultivated fruits, seeds and cereal products, nuts, and animal products, with an estimated ingestion of about 90 g dry matter of hay or grass. There were substantial differences in the feeding of cultivated fruit, compound feed, animal products and hay: eleven zoos explicitly did not feed any cultivated fruit, while in the remaining zoos the proportion of cultivated fruit in the ration varied from 0.7 to 48% of the total dry matter fed. Only 56% (n=33) of all zoos surveyed fed hay to their porcupines, and in these zoos, the average amount of non-forage items was lower, suggesting that hay ingestion is related to a lower availability of other diet items. 20% (n=11) of the zoos offered non-forage items in excess of the estimated daily intake, leading to the assumption that their animals would not have had to ingest any forages even if offered. The average body mass of zoo-kept *Hystrix* spp. was higher than that reported for free-ranging specimens, which may reflect energy-dense, forage-poor zoo diets leading to obesity. Therefore, cultivated fruit, grain products and low-fibre pellets should not be used. We suggest that zoos should adopt the recommendation to base their diets on high-quality grass hay as a staple forage, supplemented by fresh branches, green leafy vegetables, limited amounts of cultivated tubers, and a high-fibre, mineralized pellet to ensure appropriate mineral coverage. Together with our extensive literature survey, the results of this study can form the basis for husbandry guidelines for these species.

Keywords: *Hystrix*, husbandry guidelines, enclosure design, population, mortality, obesity, nutrition

Introduction

The family of the old-world porcupines (Hystricidae) is divided into two subfamilies, four genera and eleven different species (van Aarde, 1984). The most common species in European zoos are the Indian crested porcupine (*Hystrix indica*), common to south-west Asia (Grzimek, 1979/80) held in 271 zoological institutions throughout Europe (Zootierliste, 2024a), and the African crested porcupine (*H. cristata*), found in parts of central and northern Africa as well as southern Europe (Mori et al., 2013) kept in 129 European zoos (Zootierliste, 2024b).

Their most peculiar and prominent characteristic is their quill-covered back used for defence. Individual quills can reach up to 35 cm in length and are not firmly attached to the body, being often released when puncturing flesh, and leaving a predator covered in quills, inflicting pain and deep wounds. Thus among mammals, porcupines are prominent examples of prey species of the ‘defender’/body armour type, in contrast to the more common ‘escape’ type (Lovegrove, 2001). Porcupines are sometimes persecuted as agricultural pests and are also hunted for food. They are listed as “Least concern” in the IUCN red list (Amori and de Smet, 2016; Amori et al., 2021).

Under human care, *Hystrix* spp. have been reported to live up to 28 years (Weigl, 2005). Apart from parasitic infections (Hosni, 2006; Harrison et al., 2007; Mori et al., 2015a; Mir et al., 2016; Hodžić et al., 2018; Chakraborty et al., 2019; Coppola et al., 2020a, Cavallero et al., 2021,), a few infectious diseases (Jurczynski, 2011; Morandi et al., 2012; Cardeti et al., 2016; Tóth et al., 2017; Cilia et al., 2020; Cambiotti et al., 2021), dental problems (Ecinoso et al., 2023), neoplasia (Palmer et al., 2023) and intraspecific aggression (Švara et al., 2015), few problems of veterinary relevance have been published for *Hystrix* ssp. under human care, and these animals are considered easy to keep (van Aarde, 1985a). The incisors of *Hystrix* spp., as of all rodents, are hypselodont, i.e.

Tab. 1: Overview of the husbandry requirements for porcupines in different countries with a comparison to the zoos examined in this study (Bundesministerium für Ernährung und Landwirtschaft, 2014; Bundesministerium für Gesundheit und Frauen, 2004; Der Schweizerische Bundesrat, 2008).

	Germany	Austria	Switzerland	This study mean ± SD (range; n)
Enclosure size outdoors	20 m ² /pair, 5 m ² for each additional animal	40 m ² /pair	Outside 40 m ² /pair plus 4 m ² for an additional animal	65 ± 160 m ² per animal (4-1372; 79)
Enclosure size indoors	20 m ² /pair, 5 m ² for each additional animal (unless provided in addition to outdoor)		20 m ² /pair plus 3 m ² for an additional animal	4.8 ± 5.2 m ² per animal (0.3-25; 67)
Enclosure type	Outdoor-only with freeze-protected shelter allowed, indoor-only allowed	Outdoor-only with shelter allowed, indoor-only allowed	Outdoor-only allowed, indoor-only allowed	17% (n=14) zoos without indoor enclosures or heated boxes
Enclosure substrate	Soil, sand for burrowing	Soil, sand for burrowing	There must be a burrowing opportunity	5 zoos (of 80) without burrowing opportunity
Structure	Hollowed logs or dens	Hollowed logs or dens	Den for sleeping, visual barriers,	0 zoos (of 77) without shelter/den
Sociality	Pairs or small groups	Pairs or family groups	-	3.8 ± 2.7 animals (1-17; 90)
Diet	Mainly plant material and fresh branches	Fresh plant material, branches, bones with meat	Fresh branches	9 zoos (of 56) not offering branches

they are rootless and ‘ever-growing’ (van Aarde, 1985b; Ungar, 2010); their growth constantly compensates for wear in naturally aligned teeth, with problems of overshooting growth typically occurring when the physiological occlusion of antagonistic teeth is disturbed (Clauss et al., 2025). With respect to the cheek teeth of *Hystrix* spp., there is less consensus, with some authors suggesting that they are rooted and do not continue to grow after eruption (Ungar, 2010), and others stating that they are rootless with the potential for life-long compensating growth (van Aarde, 1985b). In the case of the latter condition, sporadic problems with cheek teeth, as observed in other hystricomorph rodents with ‘ever-growing’ cheek teeth such as guinea pigs (Legendre, 2016; Witkowska et al., 2017), can be expected.

Although *Hystrix* spp. are nocturnal in their natural habitats (Corsini et al., 1995; Fattorini & Pokheral, 2012; Mori et al., 2016; Clauss et al., 2021), they adapt easily to a diurnal routine in zoos (Hammer & Hammer, 2016). Due to their large size and unusual body armour, porcupines are popular zoo animals (Hammer & Hammer, 2016). In the last decade, a novel method to display porcupines was presented that increases their appeal by feeding them on an elevated platform (Hammer & Hammer, 2016). To date, no husbandry guidelines exist for these species, but certain minimum requirements are given in the animal protection legislation of individual countries (Table 1).

In their natural habitat, the diet consists mainly of various plant parts such as roots, bulbs, tubers, rhizomes, stems, leaves, flowers, wild fruit, and tree bark, and animal material like bones or insects is sometimes found in the stomach contents and faeces of *H. indica* and *H. cristata* (Hafeez et al., 2011; Akram et al., 2017; Mori et al., 2017; Khan et al., 2021; Mori et al., 2021; Mori et al., 2022; Bounaceur et al., 2024). They are known for often digging for underground storage parts of plants (Shachak et al., 1991; Bragg et al., 2005). There are also reports of wild *Hystrix* spp. as agricultural pests consuming cultivated plants such as potatoes, corn, cereals and watermelons (Alkon & Saltz, 1985; Mori et al., 2017; Khan et al., 2021). Historically, forage such as hay was not mentioned in feeding recommendations for *Hystrix* spp. in human care; rather, a large variety of domesticated tubers, vegetables, fruit and cereals have typically been recommended for these species (Weir 1967; Tohmé & Tohmé, 1980; van Aarde, 1985a; Puschmann, 2004). Together with a comparatively low metabolism (Hagen et al., 2019), the provision of such comparatively energy-dense diet items might lead to larger body masses, exceeding those of animals from undisturbed habitats.

In the present study, we aim to summarize current husbandry and feeding conditions, diseases as well as possible treatments of Indian and African crested porcupines in European zoos in the last decades, including an evaluation of necropsy reports from surveyed facilities as well as survivorship and body mass data. This information is intended as one of the bases for the formulation of husbandry guidelines for these species.

Materials and methods

Data collection: survey and interviews

We sent an online questionnaire by personal E-mail link to all European zoos keeping Indian and African crested porcupines, as identified from Zootierliste.de and Species360's Zoological Information Management System (ZIMS). Information on husbandry practices, veterinary aspects and pathological findings was collected. The questionnaire is presented in Appendix I. We contacted 280 zoos, of which 90 (32%) responded.

In addition, 18 zoos holding these species in Germany, the Netherlands and Switzerland were visited opportunistically and their porcupine husbandry investigated on-site, acquiring the same information as asked in the survey. Further information for this study was obtained in communications with specialist colleagues such as curators, veterinarians and/or keepers.

Data collection: Survivorship and body mass

Data for the historical survivorship analyses was obtained under Species360 Research Data Agreement # 2019-Q3-RR3, and included the dates of birth and death of *H. indica* and *H. cristata* across institutions around the world. We applied data cleaning as described previously for similar datasets (Meireles et al. 2025a), and retained only animals from European facilities for our analysis. The maximum attainable longevity considered in our analysis for both species was 31 years of age, based on the oldest plausible animals in the dataset (29.6 for *H. cristata* and 30.8

for *H.indica*). Any animals above this age were considered errors in recording-keeping and were entirely removed.

Data for body mass of zoo-managed animals was obtained as part of Species360 research data use agreement # 84212 as recorded in the Zoo Information Management System (ZIMS) and stored by Species360 in January 2022. The data was anonymised, indicating only the body mass entered by a zoo and the corresponding age and sex of the animal, but not the identity or the latitude of the reporting zoo. Additionally, the data did not include an indication of the reproductive status of individuals (e.g., whether animals were pregnant), and the effect of pregnancy on potential body mass fluctuations therefore could not be controlled for. Several steps were performed as explained in Meireles, et al. (2025b) to remove outlier entries from the dataset. Data for free-ranging specimens was obtained from the literature (Santini, 1980; Alkon, 1984; Alkon et al., 1986; Pigozzi, 1987a; Pigozzo, 1987b; Alkon & Saltz, 1988a; Sever & Mendelssohn, 1991; Corsini et al., 1995; Sonnino, 1998; Girish et al., 2006; Angelici et al., 2009; Mori & Lovari, 2014; Mori et al., 2015a; Coppola et al., 2020d; Vishnugurubaran et al., 2021).

Calculations and statistics

General data are displayed as means \pm standard deviation.

Historical survivorship evaluation and population pyramids: Our approach followed recent analyses for other species (see Scherer et al., 2024 for more detailed methodological discussions; Meireles et al., 2025a). In brief, we analysed the survivorship of juveniles of up to one month and up to one year of age, and the survivorship of animals that had reached one year of age separately. One year of age is about the time of sexual maturity for *Hystrix* spp. (Mori et al., 2016). The data were analysed using Cox proportional hazard analysis, indicating whether there was a change in survivorship over time (with birth year), and differences between wild-born and zoo-born and female and male individuals (see Meireles et al., 2025a for details). For graphical display, data were divided into birth cohorts (1900-1979, 1980-1999, 2000-2024). For population pyramids, animals were classified as juvenile (<1 year of age), adult (≥ 1 to 12 years of age) and seniors (≥ 12 years of age; defined as the age from which on fecundity declines).

Diet evaluation: Ideally, diet reconstruction should be based on intake data as well as on the energy content of the various diet items. As accurate intake data requires weighing offered and leftover feed over a period of several days, for the individual diet items and – ideally – for the individual animals, this was not considered feasible for this study. Similarly, nutritional analyses of items used were beyond the budget of this project. Therefore, we opted for an approach applicable to diet surveys (Flores-Miyamoto et al., 2005); such an approach is necessary in the absence of exact intake data, as certain parts of the diet are often offered in amounts that will overshoot the intake capacity of the animals (e.g., when offered for *ad libitum* consumption), especially for forage. This approach is based on the assumption that non-forage items, for which specific weights are provided, are usually consumed in total by the animals, with the rest of the intake capacity filled by forage items. Due to individual differences in appetite and intake capacity, such an approach should not be used to compare individual animals, but can serve as a rough evaluation of different diet regimes of different institutions. We assumed an average daily dry matter intake of 450 g for an individual adult porcupine based on the intake records of Alkon et al. (1986) and Hagen et al. (2019). We assumed the following percentages of dry matter (DM) in fresh matter to calculate the total amount DM offered: hay (untreated as well as pelleted or extruded), hay cobs, nuts, sunflower seeds, pumpkin seeds, cereals, oat flakes, millet, bread, rusks, dry dog/cat food and mineral supplements 90%; rice, pasta and meat (all cooked) 35%; day-old chicks and egg (cooked) 25%; fruits, vegetables, pulses, herbs and grass 15%. Reported amounts in fresh matter were transferred to dry matter using these estimates. If an animal receives less than 450 g DM per day in non-forage items

(fruits, vegetables, compound feed, nuts, seeds and cereal products, animal products and other food components), the part up to 450 g was assumed to be made up of hay or grass, or, if the zoo did not feed these forages, by branches and browse. For institutions that fed more than 450 g of dry matter per animal per day of the non-forage items, the percentage of the items was calculated and transformed to 450 g of dry matter on a proportional basis, and it was assumed that these animals would not ingest forage items.

Body mass evaluation: Our approach followed recent analyses for other species (Garand et al., 2024; Meireles et al., 2025b). In brief, we determined the cutoff for the age from which animals were considered as adult by applying a Gompertz model to the data; thus, the cutoffs for adults were 1.8 years of age for female *H. indica* and male *H. cristata*, and 2.4 years for male *H. indica* and female *H. cristata*; these data suggest that these species tend to continue to grow after having reached sexual maturity. Then body mass was first averaged per individual (using only data above the adulthood cutoff), and then across the means of all individuals; within species, females and males were compared by an independent t-test. The level of significance was set to 0.05, with p-values between 0.05 and 0.09 considered as trends.

Results and Discussion

Of the 90 European zoos that participated in this study, 69 kept *H. indica* and 21 *H. cristata*. None of the participating zoos kept both species.

Reasons for keeping *Hystrix* ssp. and display strategies

Especially because they are both attractive (with an appearance referred to as ‘dramatic’ (Martin et al., 2024)) and, due to their peculiar ‘armoured’ lifestyle, part of education programs, porcupines are popular in European zoos.

Zoos kept porcupines for several reasons; most indicated educational reasons (70%, n=63), to attract visitors (69%, n=62) and because porcupines are easy to keep (61%, n=55). Porcupines were also kept due to historical tradition (47%, n=42), low acquisition and maintenance costs (27%, n=24) the need to fill an empty enclosure (8%, n=7), or due to research (3%, n=3).

Zoos offered various events with porcupines: The most popular was public feeding or keeper talks in 44% (n=40) of all zoos. “Meet the public” took place in 9% (n=8). Behind-the-scenes tours were offered in 6% (n=5) of zoos. Guided tours with a special focus on porcupines were offered in 4% (n=4) of the zoos, with two zoos offering the opportunity to visit porcupines during a nocturnal tour. Events such as feeding the porcupines by visitors (3%, n=3), a special porcupine show (2%, n=2), a scavengers hunt about porcupines (1%, n=1) and Keeper-for-the-day with porcupines (1%, n=1) were also offered. 34% (n=31) of all zoos in the study stated that they did not offer any special events for porcupines.

Displaying porcupines on an elevated platform with minimal fencing, allowing for a particular experience of the animals without visible barriers (Hammer & Hammer, 2016), was used rarely (2%, n=2).

Husbandry

Group structure, population management and mixed exhibits

The average group size was 3.8 ± 2.7 individuals (Table 1), and an average group consisted of 1.9 ± 1.7 females, 1.5 ± 1.2 males and 0.4 ± 1.7 individuals of undetermined sex. Four zoos kept only a single porcupine. In the other 86 zoos, a porcupine group ranged from two to 17 animals.

Fewer same-sex groups were kept (twelve all-female and eight all-male groups) than groups of both sexes.

The group size of the porcupine holdings studied reflects the natural social structure: Girish et al. (2006) report two to eight animals resting together in one burrow, and Mushtaq et al. (2010) report ‘family groups’ as social structure in Indian crested porcupines. In *Hystrix* spp., both parents as well as older siblings take care of the young porcupettes, protecting them as a family unit; offspring stay with their parents for about one year, i.e. long enough to experience at least one litter of younger siblings (Coppola & Felicioli, 2021; Mori et al., 2025). Smaller group sizes ranging from pairs to solitary individuals are also described in the wild; however, the solitary animals are mostly interpreted as looking for a partner (Sever & Mendelsohn, 1991).

Asked about methods of population control, same-sex groups were the most frequently mentioned measure (39%, n=14), followed by a ‘breed and cull’ regime (28%, n=10), surgical castration of males (19%, n=7), and chemical castration (usually by deslorelin implant in females) (14%, n=5) in all zoos reporting management options. To our knowledge, there are yet no published details of using deslorelin in porcupines. While 17 zoos left the question about population control unanswered, 37 stated that they did not use any of these measures, presumably allowing animals to breed. Given that both parents and older juveniles are involved in the caring for newborn porcupettes (Coppola & Felicioli, 2021; Mori et al., 2025), it can be speculated that not allowing porcupines to breed not only curtails the natural behaviour of reproduction, but also important social behaviours they have evolved.

In three of the ten zoos that used a ‘breed and cull’ regime, porcupine carcasses were fed to other zoo animals, typically after skinning the carcass. One zoo once fed a culled porcupine to a lynx (*Lynx lynx*) without skinning beforehand, which was not accepted by the lynx. These feedings took place in public and were explained explicitly by use of signs, live narration during the feeding or via social media. Notably, the breed-and-cull strategy was not peculiar to porcupine management at these facilities, but applied to a larger number of different animals.

In 19 of 90 zoos, porcupines were kept together with other species. The most common species in all associations were meerkats in five institutions, followed by guinea pigs in two. Other combinations only occurred once, including northern tree shrew (*Tupaia belangeri*), Prevost’s squirrel (*Callosciurus prevostii*), another porcupine species (*Hystrix africaeaustralis*), ring-tailed lemur (*Lemur catta*), lar gibbon (*Hylobates lar*), white-naped mangabey (*Cercocebus lunulatus*), mongoose (*Herpestidae*), Bactrian camel (*Camelus bactrianus*), Vietnamese pig (*Sus scrofa domestica*), zebras (*Equus* sp.), blue peafowl (*Pavo cristatus*), Eurasian eagle-owl (*Bubo bubo*), Eurasian griffon vulture (*Gyps fulvus*), marabou stork (*Leptoptilos crumenifer*), and various other bird species. Negative effects resulting from socialization were described only in three of these multi-species exhibits: In one zoo, porcupine quills were found sticking in the legs of Bactrian camels; problems with meerkats were described in two other zoos. In one of these, meerkats attacked young porcupines; in the other, there were disputes during feeding, which were easily resolved by separating the species during feeding events. Serious veterinary problems resulting from socialising porcupines with other species were not described in any zoo.

When keeping *Hystrix* spp. together with other species in mixed exhibits, precautionary measures are recommended, ensuring that the species do not get into conflict at feeding stations or do not ingest inappropriate food items targeted to other species. Even for free-ranging porcupines, conflicts with roe deer (*Capreolus capreolus*) at common feeding sites have been reported, with porcupines invariably being the aggressive, attacking party (Lazzeri et al., 2020). In natural habitats, porcupines are known to share their burrows with other species, especially badgers (Mori et al., 2015b; Mukherjee et al., 2019; Coppola et al., 2020b); to what extent this would be possible in a confined management remains to be tested.

Enclosure design

In the absence of husbandry guidelines, legal requirements for the husbandry of zoo animals can be compared to the results of our survey. The legal requirements of Germany, Austria and Switzerland for the husbandry of *Hystrix* spp. are summarised in Table 1. Generally, the requirements noted in this legislation were met.

The average enclosure size was $164 \pm 196 \text{ m}^2$ (10-1372 m^2 ; $n=79$) for outside and $14 \pm 18 \text{ m}^2$ (2-100 m^2 ; $n=67$) for inside enclosures (see Tab. 1 for areas per animal). Thus, the average porcupine enclosure in this study was about eight times larger than required by German, and about 4 times larger than required by Austrian and Swiss minimum requirements (Tab. 1). Saltz & Alkon (1989) measured a mean home range in free-ranging *H. indica* of $1.5 \pm 0.4 \text{ km}^2$ and a nocturnal movement of $2.8 \pm 0.7 \text{ km}$; for an undisturbed habitat, Sever & Mendelsohn (1991) documented a similar home range size of about 1.2 km^2 for a pair. By contrast, these authors documented a smaller home range in agricultural areas (about 0.4 km^2), suggesting that the higher food availability limits the necessity to roam. Natural home range sizes are a result of resource density; nevertheless, it is considered desirable to facilitate similar movement rates in zoo animals as compared to free-ranging specimens. Corresponding measurements are lacking in zoo porcupines, but it is reasonable to suspect that the more often, throughout the day, smaller portions of the daily food ration are given at different locations, the more the animals will move around. In this respect, it would be desirable if more zoos would abandon a one-feeding-per-day regime (see below).

Most zoos kept their porcupines in a combination of indoor and outdoor enclosures (70%, $n=57$); exclusively outdoor keeping without (17%; $n=14$) or with heated boxes (10%; $n=8$) also occurred. Indoor-only housing was rarely practised (4%; $n=3$) (Tab. 1). The question of indoor facilities is regulated differently in the husbandry recommendations of the various countries. Germany requires a frost-free shelter in winter, while Austria and Switzerland only require shelters or sleeping boxes. Haim et al. (1990) report on the thermoregulatory abilities in Cape porcupines (*H. africae-australis*), which can regulate their body temperature between 13°C and 30°C when acclimatised to 25°C . Coppola et al. (2019) note that there is no comparable data for *H. cristata* and *H. indica*, but suggest similar abilities in these two species. *H. cristata* also have to contend with temperature differences in the wild, as Italian summers can be distinctively warmer (23.1°C) than the average winter temperature of 6.8°C (Coppola et al., 2022). *H. indica* also experiences strong seasonal temperature fluctuations: Taslim et al. (2022) report average temperatures of 14°C in winter and 35°C in summer. Khan et al. (2021) even report a temperature range of 2°C to 40°C for *H. indica*. There are also reports of wild *H. cristata* and *H. indica* living around freezing point (Prakash, 1975; Osunsina et al., 2010). It has been suggested that the limitation of the range of *Hystrix* species is not set by temperatures, but by seasonal daylight hours; because porcupines, as nocturnal foragers, depend on a certain length of night to find sufficient amounts of food, they may not occur at latitudes where summer nights are shorter than seven hours (Alkon & Saltz, 1988b). In view of the geographical distribution and adaptability of porcupines, no objections can be raised with regard to the temperature at the zoos participating in our survey.

The substrate most often used in indoor enclosures was straw - either alone or in combination with other substrates (63%, $n=43$), followed by concrete (31%, $n=21$), wood chips (29%, $n=20$), hay (15%, $n=10$), bark (10%, $n=7$), sand (4%, $n=3$), tiles (3%, $n=2$), a rubber mat (1%, $n=1$) and clay (1%, $n=1$). In outdoor enclosures, sand (56%, $n=44$) and topsoil (49%, $n=39$) occurred most frequently, followed by bark (23%, $n=18$), grass (15%, $n=12$), concrete (10%, $n=8$), stones (8%, $n=6$), gravel (6%, $n=5$), clay (5%, $n=4$), paving (3%, $n=2$), wood (3%, $n=2$), straw (1%, $n=1$), mineral mixture (1%, $n=1$), silica (1%, $n=1$) and artificial grass (1%, $n=1$). Burrowing was not possible for the animals in 4% ($n=3$) of outdoor enclosures, and not in 2 of the 3 indoor-only enclosures. Thus, the requirements for burrowing opportunities were mostly met. In natural habitats, porcu-

porcupines dig out burrows or dens, which they occupy with up to eight animals; Girish et al. (2006) estimated that for one burrow, soil of the magnitude of 50-60 kg was moved, and reported that ‘a lot of time and energy was expended in burrowing activity’. Facilitating burrowing behaviour is therefore considered important in porcupine husbandry (Martin et al., 2024). Information on how often porcupines dig new burrows is lacking to our knowledge, but Girish et al. (2006) claim that porcupines preferred to dig fresh burrows rather than occupy those abandoned by other animals. This raises the question whether zoo management practices allow for repeated burrowing activity. Unfortunately, we did not specifically ask about whether zoos regularly ‘flattened’ their outside enclosures, filling the burrows (while animals are locked into another enclosure), to induce new digging activity by their animals. Possibly, doing this on an annual basis, coupled with a shifting of structural enclosure elements, could represent an important enrichment measure for zoo porcupines that could also invite visitor attention and establish a local ‘husbandry tradition’.

The structural elements in porcupine outdoor enclosures included wood or tree trunks (70%, n=54), stones (56%, n=43) and artificial tunnels or caves (48%, n=37). Roots (10%, n=8), plants (9%, n=7), hills (8%, n=6), platforms (8%, n=6) and ponds (8%, n=6) were also used. Concrete (3%, n=2), artificial rocks (1%, n=1), heat lamps (1%, n=1) and metal (1%, n=1) were also found in the outdoor facilities of porcupines. In contrast to the outdoor enclosures, indoor facilities were usually rather poorly furnished. 45% (n=27) of all zoos with indoor facilities explicitly reported that they do not use any structural elements indoors; notably, all of these 27 zoos also had an outdoor enclosure, so that the indoor enclosure might have been considered as a ‘den’ in itself. Otherwise, tree trunks (41%, n=13) and burrows (22%, n=7) were most frequently used in indoor enclosures. Heat lamps (13%, n=4), rocks (6%, n=2) and plants (3%, n=1) were only used occasionally. The indoor enclosures of 59% (n=38) of all zoos with an indoor facility included a separation option. Since porcupines usually sleep in dens in the wild, and also use these to raise their offspring (Haim et al., 1992a; Corsini et al., 1995; Mukherjee et al., 2019), providing hiding places not only in outdoors but also at least in those indoor enclosures that surpass the typical size of a ‘den’ should be considered.

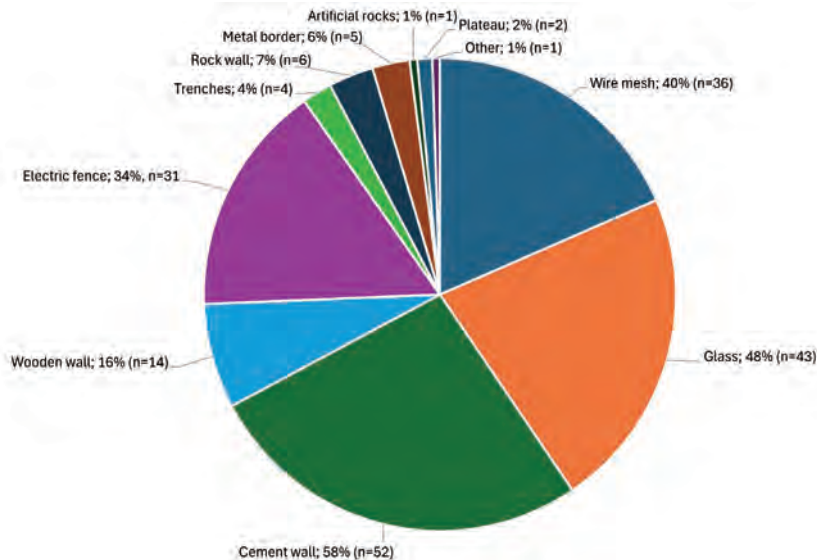


Fig. 1: Used barriers at enclosures of Indian crested porcupines (*Hystrix indica*) and African crested porcupines (*Hystrix cristata*) kept in European zoos.

Various barriers were used for porcupine enclosures (Fig. 1). On average, the lowest point of enclosure barriers was 118 ± 77 cm (30–500 cm; $n=70$). Cement walls (58%, $n=52$) were most frequently used, followed by glass (48%, $n=43$), wire mesh (40%, $n=36$) and electric fencing (34%, $n=31$). When porcupines are presented on an elevated platform (2%, $n=2$), no fencing might be necessary due to the animals' fear of heights; however, some barrier that prevents visitors from touching the animals may be necessary (Hammer & Hammer, 2016). Most zoos secured their porcupine enclosures with a burrow protection system (i.e., underground enclosure barriers). Only four of the zoos in the study (5%) explicitly stated that they did not use burrow protection. The most common types of burrow protection used were concrete (34%, $n=25$), mesh (24%, $n=18$) and grids (19%, $n=14$). A deep wall extending into the ground or a deep sunk strip foundation (4%, $n=3$), (cobble)stones (3%, $n=2$) and tiles (1%, $n=1$) were used less frequently. Porcupines are considered escape artists and have already escaped at least once in 30% of the zoos surveyed. The main causes for escaping were climbing over the fence (41%; $n=10$), digging out (29%; $n=7$) and human error in the form of incorrectly closed doors (21%; $n=5$).

Handling and training

93% of the surveyed zoos kept their porcupines in direct contact ($n=75$), with only 7% ($n=6$) using indirect contact. However, in 19% ($n=15$) of the zoos, porcupines had caused injuries to humans. The greatest danger in porcupine husbandry comes from the quills, as 87% ($n=13$) of all injuries were caused by the quills; in only 13% ($n=2$) were humans bitten by porcupines. The most common methods of catching porcupines were drift boards (36%; $n=32$) and catch cages (36%; $n=32$). Nets (24%; $n=22$) and distance immobilisation (24%; $n=22$) were also frequently used. Crate or target training, in which the animals voluntarily enter a transport crate, occurred less frequently (4%; $n=4$). Medical behaviour training was practised by only 23% ($n=19$) of the zoos surveyed (Fig. 2). Mainly target training was conducted, but mouth examinations, crate and weighing training were also performed occasionally.

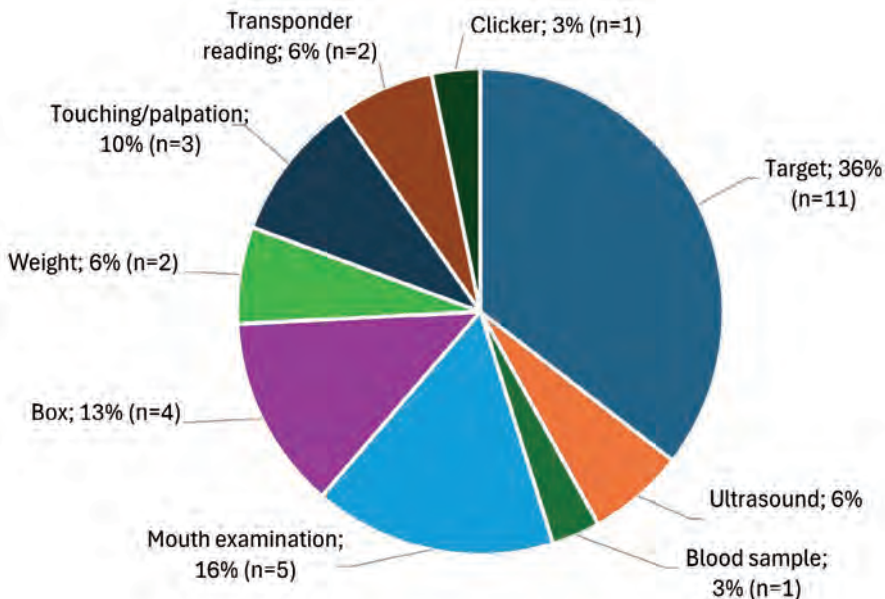


Fig. 2: Medical behaviour training in Indian crested porcupines (*Hystrix indica*) and African crested porcupines (*Hystrix cristata*) kept in European zoos.

Anecdotal information passed on during interviews in the present study, as well as personal observations of some of the authors (MP, MC) support the notion that *Hystrix* spp. will change their behavioural pattern from strict nocturnal activity to diurnal activity under human care (Hammer & Hammer, 2016). Thus, it is possible to present active porcupines during daylight hours. The various reports of training with porcupines support the personal observation of the authors (MP, MC) and a literature review (Martin et al., 2024) that porcupines are used as ambassador animals in training displays in some institutions, and a case report that describes the process by which a porcupine was trained to keep touching a target with its nose for 30 consecutive seconds (Fernandez & Dorey, 2021).

Veterinary aspects

Porcupines seem to rarely get clinically sick in human care: 51 zoos (57%) explicitly reported that they had no health problems in their porcupines. This is consistent with the results of the literature search, where only few porcupine diseases are described. Of the 46 reported medical problems, 22% (n=10) were skin-related, of which half were skin wounds due to intraspecies aggression in the form of bites (Fig. 3). Other frequently affected organ systems were the respiratory tract (20%, n=9), mostly in the form of pneumonia, the teeth (17%, n=8), the gastrointestinal tract (11%, n=5) and the reproductive tract (11%, n=5). Diseases of the eyes (9%, n=4), the musculoskeletal system (7%, n=3) and neurological diseases (2%, n=1) were also mentioned.

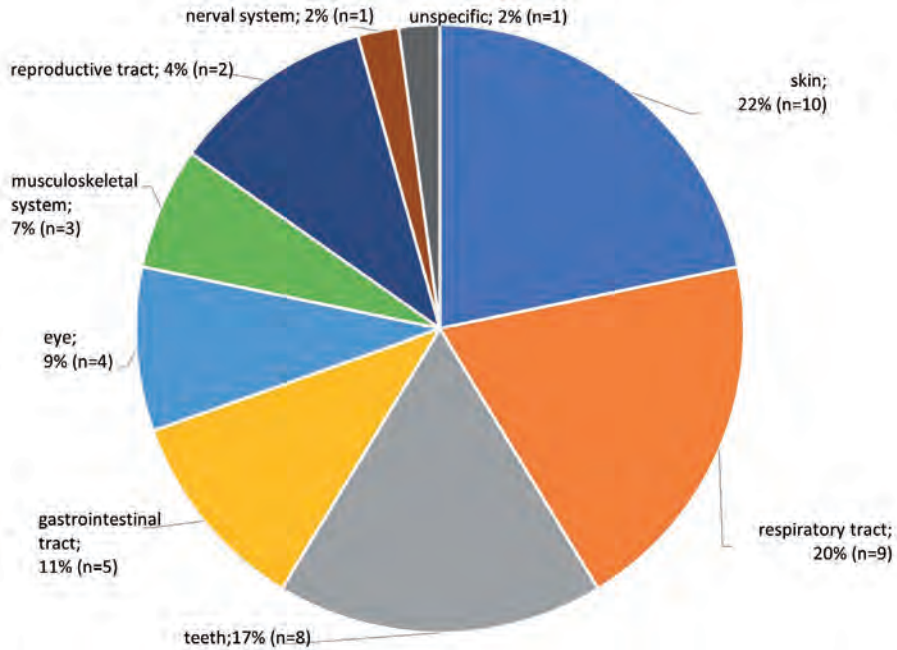


Fig. 3: Affected organ systems in diseased Indian crested porcupines (*Hystrix indica*) and African crested porcupines (*Hystrix cristata*) kept in European zoos.

We received a total of only 31 necropsy reports from 16 zoos, of which nine applied to juvenile animals (<1 year of age) and 22 to adult animals. Evidently, more consistent pathological screening of dead porcupines is recommended. The average age of these animals was 7.7 ± 9.2 years; for juveniles, this was 0.2 ± 0.2 years (range seven days to five months), and for adult animals 10.3 ± 9.3

years (range 1 to 26). In comparison, the median age of adult animals in the most recent cohort of European animals (born between 2000 and 2024) was 15.5 years for the Indian and 14.6 years for the African crested porcupine (Fig. 4).

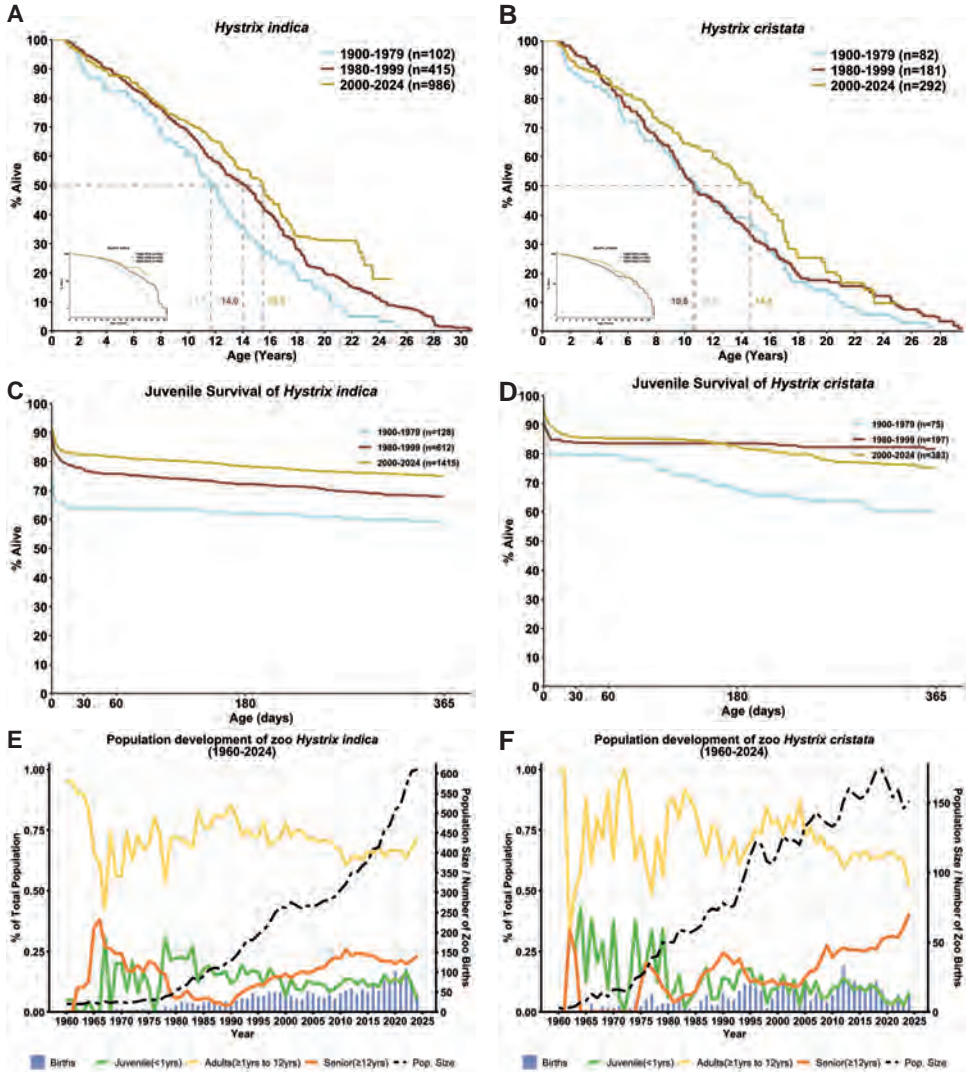


Fig. 4: Adulthood survivorship, juvenile survivorship, population development for *Hystrix indica* (A, C, E) and *Hystrix cristata* (B, D, F). Note the higher survivorship in more recent cohorts, and the increase in senior and the decrease in juvenile animals in the populations.

Cause of death

Among the organs affected in the 25 necropsy reports of adult animals, the respiratory tract was most frequently mentioned at 32% (n=11), followed by the gastrointestinal tract (21%, n=7), neoplasia (9%, n=3), kidney disease (9%, n=3) and the skin (9%, n=3, with 2 cases again being

attributable to intraspecies aggression in the form of bites and puncture wounds). Cardiovascular tract (6%, n=2), neurological pathologies (6%, n=2), reproductive tract (3%, n=1), and sepsis (3%, n=1) played a minor role. Juvenile animals were most frequently affected by cardiovascular problems (27%, n=3) and respiratory problems (27%, n=3), followed by skin problems (18%, n=2) caused by aggression, and sepsis (18%, n=2).

The drugs used in Indian and African crested porcupines and the corresponding dosages are listed in Appendix II; this table also contains literature information on dosages in porcupines.

Infectious diseases

Infectious agents diagnosed in *H. indica* and *H. cristata* by the participating zoos are listed in Appendix III. Only a few bacterial diseases in porcupines have been described in the literature: Porcupines are susceptible to tuberculosis caused by *Mycobacterium pinnipedii* (Jurczynski et al., 2011) and *Mycobacterium bovis* (Cambiotti et al., 2021). Leptospirosis is described in *H. cristata* (Cilia et al., 2020). *Micrococcoides hystricis* was first isolated in 2017 from *H. indica* of Budapest Zoo (Tóth et al., 2017). Kleinerman et al. (2021) detected *Borrelia persica* in wild-living *H. indica*.

Whereas *Aspergillus fumigatus* is the only fungal infection described in this study, there is also only one published case of fungal disease in porcupines: Adiaspiromycosis caused by *Emmonsia crescens* is described in one young male free-living *H. cristata* in Italy (Morandi et al., 2012).

The surveyed zoos had no known problems with viral diseases in porcupines, and only two relevant viruses have been described in the literature to date, to our knowledge: Encephalomyocarditis virus (EMCV) caused myocarditis and asymptomatic deaths with a mass mortality in porcupines in a rescue center during winter (Cardeti et al., 2016). *Pasalabepivirus balayani* (hepatitis E virus) is described in free-ranging porcupines, possibly due to sharing the habitat with wild boars (*Sus scrofa*) (Pierini et al., 2021; Pirani et al., 2023); the clinical relevance remains unknown.

41 zoos (46%) stated that they regularly tested for endoparasites (mostly using flotation) but had not yet been able to detect any endoparasitoses in their porcupines. Apart from this statement, we received 85 specific test results from porcupine faecal examinations from eleven zoos, of which 72 (85%) were negative. The most frequently detected parasites were *Trichuris* spp. in ten samples, followed by Strongylidae in three samples and Giardia and Flagellates in a single sample each. Similarly to our study, parasitic problems appear to be rare in porcupines under human care in the literature. *Trichuris* spp. and Ascarids were diagnosed in captive Indian crested porcupines in a small zoo in India (Mir et al. 2016). Rivero et al. (2022) found that *Trichuris* spp. isolated from zoo-housed porcupines had a high similarity with *Trichuris landak* and mentioned *Trichuris hystricis*, *Trichuris lenkorani* and *Trichuris mettami* as the other most common *Trichuris* species in porcupines. Varadharajan (1999) detected *Toxocara* sp., *Strongyloides* sp., Strongyle eggs and *Trichuris* sp. in zoo-housed Indian crested porcupines. Durette-Desset (1966) found two new Trichostrongyles in crested porcupines living in a Vietnamese zoo: *Longistriata levanboai* and *Longistriata cordicauda*.

In free-ranging specimens, more endo- and ectoparasitoses are diagnosed compared to zoo-housed porcupines, probably due to veterinary surveillance and high standards of hygiene under human care. Self-medication of porcupines by deliberately ingesting plants with antiparasitic properties has been suggested (Viviano et al., 2022). *Linguatula serrata* plays an important role as a zoonotic parasite in *H. indica* in the Middle East (Rajabloo et al., 2015) but does not occur in animals kept in European zoos, possibly due to a lack of intermediate rodent hosts. *Toxoplasma gondii* can cause neurological symptoms in *H. cristata* (Harrison et al., 2007). Coppola et al. (2020a) detected gastrointestinal strongyles, *Trichuris* spp., *Capillaria* spp., *Giardi* spp., *Giardi duodenalis*, Coccidea and *Cryptosporidium* spp. in free-ranging *H. cristata* in Italy. *Trichuris* spp. were also described in free-ranging *H. cristata* in Italy (Poglayen et al., 2005; Coppola et al., 2020c; Cavallero et al., 2021; Viviano et al., 2022) and in free-ranging *H. indica* in Iran (Youssefi et al., 2010). *Archeostromylus italicus* was de-

scribed repeatedly in wild-living porcupines in Italy (Biocca & Ferretti, 1957, Poglayen et al., 2005, Viviano et al., 2022). *Trichostrongylus orientalis* was found in free-ranging *H. indica* in Iran (Ghadirian & Arfaa, 1972). Chakraborty et al. (2019) described *Dipylidium* sp. and *Parascaris* sp. in wild-living Indian crested porcupines in India. Furthermore, porcupines are susceptible as accidental hosts to *Echinococcus ortleppi* (Hodžić et al., 2018) and to *Trichinella* spp. (Hosni, 2006) as well as for *Taenia twitchelli*, which was found in porcupines' lungs and has zoonotic potential (Yarto-Jaramillo, 2015).

Fleas and ticks are the most seen ectoparasites in wild-living African crested porcupines in central Italy: *Pulex irritans*, *Ixodes ricinus*, *Rhipicephalus bursa*, *Phlebotomus hexagonus*, *Ixodes ventraloi*, *Paraceras melis*, *Ctenocephalides canis*, *Dasytyssyllus gallinulae* and *Hystrichopsylla talpae* (Mori et al., 2015a). Parola et al. (2005) described *Parodontis riggenbachi* in porcupines. Viviano et al. (2022) found *Ixodes ricinus*, *Phlebotomus hexagonus*, *Pulex irritans*, *Dasytyssyllus gallinulae*, *Paraceras melis*, *Ctenocephalides canis* and *Hystrichopsylla talpae* in wild-living African crested porcupines in central Italy with different prevalences during the year. A traumatic myiasis caused by *Calliphora vicina* was described in a porcupine by Scaravelli et al. (2017).

The endoparasite prevalence of 15% in this study is significantly lower than in other retrospective parasite studies in zoo-housed porcupines and other species, where it is usually between 31.1 and 68.3% (Lim et al., 2008; Fagioloni et al., 2010; Barbosa et al., 2020; Murnik et al., 2024). Possible reasons for this are the lower animal density in porcupine husbandry or better hygiene standards in porcupine husbandry. Since many zoos detect endoparasites using flotation and the sensitivity of this test depends, among other things, on the skill of the person performing it, differences in the sensitivity of the diagnostic method used could also be a possible reason for the varying prevalence.

Non-infectious diseases

Dental problems were among the more prominent non-infectious diseases in this study, which align with the literature. In free-ranging African crested porcupines, dental abnormalities are rare (Angelici & Luiselli, 1999). In zoo animals, excessive growth of incisors has been described without a clear indication of the prevalence (Yarto-Jaramillo, 2015). This has been linked to the fact that rodent incisors are 'ever-growing', and it is assumed that any cause leading to malocclusion and/or a lack of a fibrous diet that 'keeps incisors from overgrowing' are responsible (Yarto-Jaramillo, 2015, Martin et al., 2024). However, given ample evidence that the growth of such incisors is controlled by pressure of the antagonist tooth irrespective of the abrasiveness of fibrosity of the diet (Opsomer et al., 2025), malocclusion is the most likely etiopathology – which might be caused by dietary factors unrelated to the diet's abrasiveness but linked to its content of fibre and easily digestible carbohydrates (Clausen et al., 2025). Neither the present study nor the literature report cheek tooth overgrowth in *Hystrix* spp. as found for example in guinea pigs (Yarto-Jaramillo, 2015), favouring the view that *H. indica* and *H. cristata* cheek teeth are not ever-growing (as opposed to a literature report on *H. africanaustralis*, van Aarde, 1985b). Wolters & Foreest (2003) described a root abscess in the mandibular molar of an African crested porcupine that was treated by extraction of the affected tooth, and after six weeks, the maxillary antagonist had not overgrown, supporting this view; by contrast, Angelici & Luiselli (1999) report the lack of a maxillary premolar in a *H. cristata* skull that evidently led to overgrowth of the corresponding mandibular premolar. Computed tomography images of *H. cristata* skulls (Encinoso et al., 2022; Bordon et al., 2024) do not provide a conclusive answer as to whether these teeth have roots or not (and note that the latter authors also describe the basis of the incisors as 'roots'). Given the large number of *Hystrix* porcupines available across European zoos, a more detailed, conclusive examination of the nature of their cheek teeth to resolve the question whether they are rooted or rootless (and hence, have the capacity for compensating growth throughout the animals' lives), would be welcome.

With respect to intra-specific aggression, one Indian crested porcupine died in a Slovenian zoo after fighting with a conspecific due to a puncture injury that perforated the chest and led to septicemia (Švara et al., 2015). Management practices to regulate animal density in an enclosure, offer a sufficient number of feeding location and structural elements to allow animals evading each other are likely important to reduce intra-specific aggression.

Skin lesions can otherwise be iatrogenic due to trauma by distance injection (Yarto-Jaramillo, 2015). Skin lesions are best sutured with thin threads with atraumatic needles, comparable to material used in avian medicine (Yarto-Jaramillo 2015). To detect the cause of a neurologic disease an MRI can be performed. Anatomical areas of healthy porcupines are described in MRI by Morales-Bordon et al. (2023). Neoplasia in porcupines is rarely described in the literature and was rare in this study; Palmer et al. (2023) reported four cases of mammary adenocarcinoma in zoo-housed Indian crested porcupines.

Historical survivorship

Both Indian and African crested porcupines have shown rapid population growth in European zoos since 1960, although the latter has been declining slightly for the past five years (Fig. 4). In

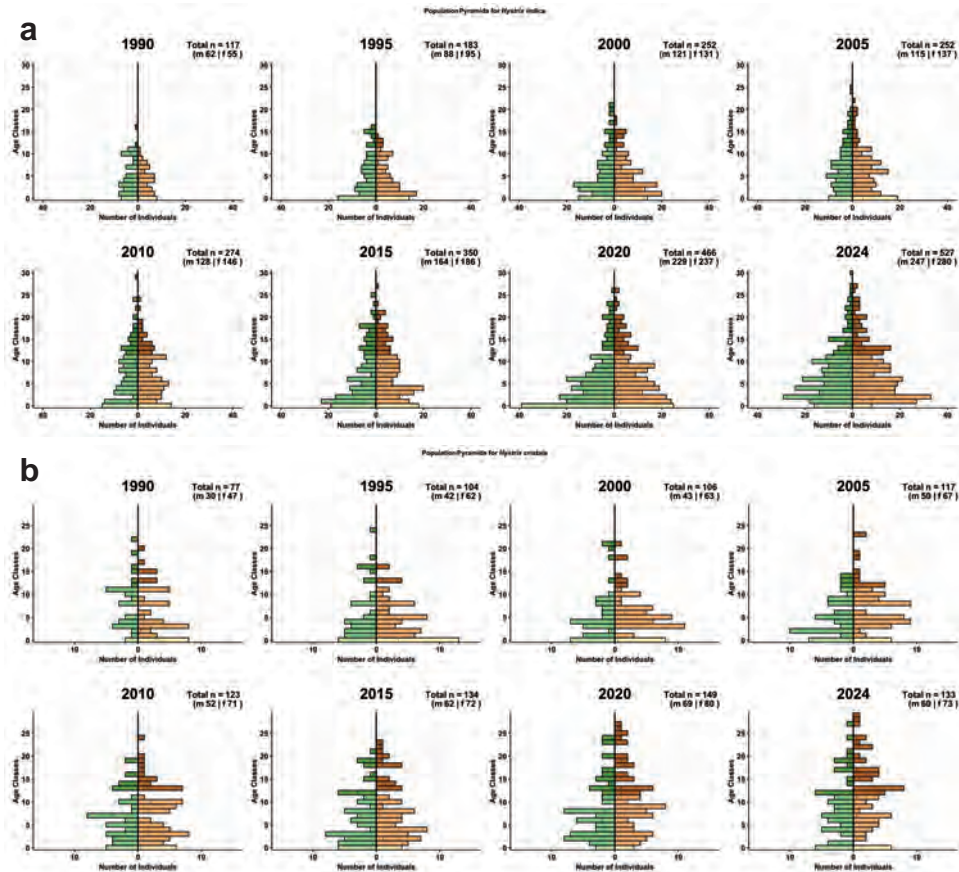


Fig. 5: Population development for *Hystrix indica* (a) and *Hystrix cristata* (b) displayed as population 'pyramids'. Note the recent development towards a columnar shape in the *H. cristata* population.

both species, the proportion of senior animals increased and that of juveniles decreased, with the trend being more distinct in the smaller population of the African crested porcupine (Fig. 4). The 'population pyramid' consistently had an (expanding) pyramid shape over time in *H. indica*, but a more distinct columnar shape in *H. cristata*, corresponding to the decreasing population size in the latter (Fig. 5). A recent decline in births was evident in both species.

In both species, the graphical display of the survivorship of birth cohorts in adults and juveniles (Fig. 4) suggests improvements over historical time. For both species, the survivorship plots indicated a type I survivorship curve (Deevey, 1947) with an overall low mortality (Fig. 4A,B inlets). This is typical for long-lived mammals that give birth to precocial young that are not exposed to distinct predation. In *H. cristata*, the historical improvement failed to reach statistical significance; in adults, birth year just showed a corresponding trend ($n=402$, $z=-1.71$, $p=0.087$), and there was a numerical increase in the median lifespan of adult animals from 10.6 to 14.6 years. No significant historical trend resulted for the juvenile first month ($n=656$, $z=0.118$, $p=0.906$) and first year ($n=656$, $z=1.145$, $p=0.252$) survivorship. In all these cases, there was also no significant difference between males and females. In *H. indica*, some of the visual trends were significant. For adults, birth year again only showed a corresponding trend ($n=1207$, $z=-1.87$, $p=0.061$), and there was a numerical increase in the median lifespan of adult animals from 11.7 to 15.5 years. In juveniles, the historical improvement of survivorship was significant for the first month ($n=2158$, $z=-5.20$, $p<0.001$) and first year ($n=2158$, $z=-5.07$, $p<0.001$) survivorship. While there was no significant difference between males and females for adult and juvenile first month survivorship, males were less likely to survive until one year of age than females ($n=2158$, $z=2.69$, $p=0.007$). It is difficult to pinpoint any specific husbandry measure to this progress. Similar results have also been demonstrated for other species such as African and Asian elephants, giraffes, and pygmy hippopotamuses (Scherer et al., 2023; Scherer et al., 2024; Meireles et al., 2025a). The lower positive improvement in juvenile and adult survivorship in *H. cristata* and the slight decline in this population over the last five years may be due to the clearly smaller population size in Europe and to the more pronounced obesity (see below), which is very common in the majority of individuals.

Whereas the European zoo population of *H. indica* is thriving, with a robust pyramid-shaped population structure, that of *H. cristata* appears less resilient with a columnar population structure (Fig. 5). The greater variation in the number of adult *H. cristata* over the years can be attributed to the smaller population size, as no differences in veterinary and pathological characteristics were found between the two porcupine species studied. As neither species is classified as endangered, no re-introduction programs are foreseen even in the mid-term future, and no clear differences between the species seem to exist that would lead to differences in their educative value, it might be advisable for European zoos to focus on the *H. indica* species and phase-out *H. cristata*.

Dietary management and body mass

Detailed data on porcupine feeding was available from 56 zoos. The majority of zoos (64%, $n=36$) fed their porcupines once per day, 25% ($n=14$) offered food two times, 5% ($n=3$) 3-4 times, and another 5% ($n=3$) gave food at a higher frequency multiple times across the day. Putative benefits of higher feeding frequencies have been mentioned above.

There was enormous variation in diet composition, with diets that were based mainly on grass hay, diets based mainly on pelleted food, and diets based mainly on vegetables (Fig. 6). Out of 56 zoos, 45% ($n=25$) did not offer grass hay. The amount of dry matter provided in non-forage items averaged at 361 g, with a large range from 22 to 1010 g per animal (Table 2). In comparison to the assumed 450 g of dry matter intake per adult individual, 20% ($n=11$) of the zoos offered non-forage items in excess of that threshold, leading to the assumption that these animals would not have had to ingest any forages even if offered. This seems to be confirmed by noting that 8 of

Tab. 2: Total amount of non-forage (no hay, grass or branches) items offered in dry matter (DM) per animal and day, the estimated* DM intake of individual food categories incl. hay/grass and branches per animal and day (and the % of total assumed intake) in Indian (*Hystrix indica*) and African crested porcupines (*Hystrix cristata*) in 56 European zoos.

	Total non-forage	Vegetable	Fruit	Seeds Cereals	Nuts	Animal matter	other	Pellet	Hay Grass	Branches
	g DM									
	(% of total assumed DM intake)									
Mean	322 (72%)	161 (36%)	40 (9%)	13 (3%)	10 (2%)	4 (1%)	1 (0%)	93 (21%)	93 (21%)	34 (8%)
SD	197	100	48	31	18	12	6	104	113	678
min	22	0	0	0	0	0	0	0	0	0
max	1020	433	216	159	79	73	34	366	428	283

*assuming a total daily dry matter intake of 450 g per adult animal (Hagen et al. 2019), and a complete ingestion of non-forage feeds offered; for details see methods

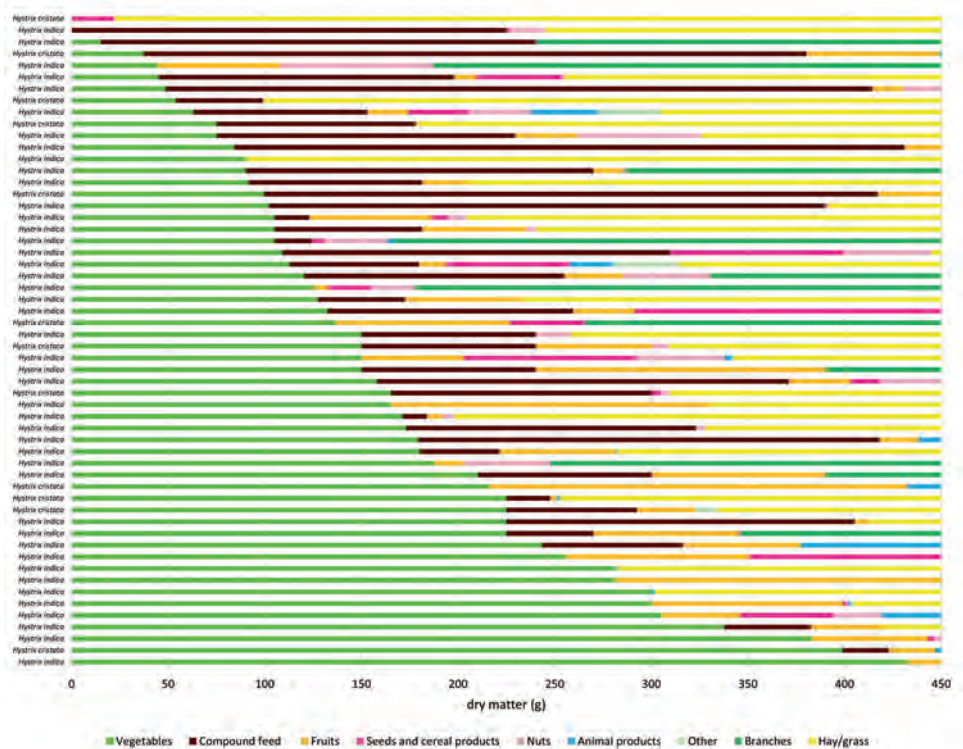


Fig. 6: Proportion (on a dry matter basis) of hay/grass, fruits, vegetables, compound feed, nuts, seeds and cereal products, animal products, branches and other foods in the diet of Indian crested porcupines (*Hystrix indica*) and African crested porcupines (*Hystrix cristata*) in European zoos.

these 11 zoos (73%) did not offer hay or grass to their porcupines. Of the remaining 45 zoos that fed non-forage items at amounts below that threshold, only 17 (38%) did not offer hay or grass. Zoos that did not offer grass or hay offered an average of 432 ± 236 g DM (range 167-1020 g) of non-forage items per animal, whereas this was 304 ± 140 g DM (range 22-678 g) of non-forage

items in zoos that offered grass or hay. Only 9 zoos (15%) did not offer gnawing material in the form of branches to their porcupines.

On average, vegetables represented the largest proportion of estimated dry matter intake, (and were used in 54 zoos) followed by compound feeds (pellets, in 39 zoos) and hay; in decreasing proportion, fruit (in 42 zoos), seeds/cereals (in 19 zoos), nuts (in 24 zoos), animal matter (in 24 zoos) and others represented much lower average proportions (Table 2). 72% of the zoos (n=42) fed one or several compound feed products to their porcupines; the products were of a huge variety, including products for rodents (n=16), dogs and cats (n=12), rabbits (n=9) and birds (n=2); there was no product that was used predominantly. The animal matter offered included deer antlers (n=10), other bones (n=15), eggs (n=7), cooked meat (n=5), day-old chicks (n=1). Minerals and supplements were given in 22% of zoos (n=13).

Some diets were traditional in the sense of Fens & Clauss (2024), as anthropomorphic diet items such as bread, grains and cultivated fruits are still fed quite often (as suggested for porcupines by Weir, 1967; Tohmé & Tohmé, 1980; van Aarde, 1985a; Puschmann, 2004, Hagen et al., 2019). So to speak, many zoos use the feeding habits of “pest” porcupines that feed on agricultural products as guidelines for their feeding regime, not the feeding habits of porcupines from unmodified habitats. This is in distinct contrast to current recommendations, which state explicitly that grass hay, grasses, vegetables and high-fibre pellets low in starch and soluble carbohydrates should be fed, and that warn against the use of cultivated fruit, grains and commercial dog and cat food (Yarto-Jaramillo, 2015). Fens & Clauss (2024) suggested that, in the face of existing recommendations, the fact that some zoos continue to use anthropomorphic diets may have cultural rather than biological reasons.

The data of the present study can be interpreted as a state of transition with respect to dietary regimes. The amount of cultivated fruit fed ranged from 0 to 216 g of dry matter per animal and day; eleven zoos explicitly reported that they do not feed any fruit to porcupines, but on the other hand, eleven zoos offered non-forage diet items at magnitudes above the assumed daily dry matter intake of porcupines. The proportion of zoos that did and did not include grass hay in the diet of their porcupines was nearly even (55% vs. 45%). Across all zoos, the amount of non-forage diet items appeared roughly balanced against the offer of forage items, suggesting that if forced to do so, porcupines do ingest, and use, forages; as a conclusion, we suggest that all zoos should adopt the recommendation to base their diets on high-quality grass hay as a staple forage, supplemented by fresh branches (a legal requirement in several countries), green leafy vegetables, only very limited amounts of cultivated tubers, and a high-fibre, mineralized pellet to ensure appropriate mineral coverage. For example, the feeding experiment of Hagen et al. (2019) showed that porcupines do ingest relevant amounts of a high-fibre, lucerne-based pellet – if no other diet items are available.

Three important consequences will ensue if forage-based, high-fibre diets are not used. First, porcupines on diets of higher nutrient density (i.e., lower fibre content) are less likely to practice coprophagy. Coprophagy is an evolved digestive adaptation of various mammal taxa, including lagomorphs, muroid rodents and hystricomorph rodents such as *Hystrix* spp., where the gut bacteria (a valuable protein source) are not excreted with the normal faeces but retained, by a separation mechanism in the colon, and excreted as ‘soft faeces’ that are ingested by the animal directly when excreted from the anus (reviewed in Clauss et al., 2023). Even though *Hystrix* spp. have the anatomical prerequisite for the colonic separation mechanism (Hagen et al., 2019), this behaviour has long been considered nonexistent in these species until confirmed visually very recently (Polotzek et al., 2023). Because coprophagy is a nutritional behaviour that is not expressed on nutrient-dense diets (Hagen et al., 2015; Guerra Aldrigui et al., 2018), the historical feeding practices still used in some of the investigated zoos may have contributed to the impression that porcupines do not practice coprophagy. This issue raises the general question how feeding practices in zoos can affect natural behaviours (e.g., Friedmann et al., 2023; Bähler et al., 2024).

Second, diets consisting of energy-dense items typically require less ingestion time until saturation is reached, even though voluntary intake of these items will often overshoot energetic requirements, as demonstrated in rabbits (Prebble et al., 2015a). Even though similar investigations in porcupines are lacking, it is plausible to assume that they would be active for larger parts of the day if fed diets higher in fibre and lower in energy density. Given the large variety in porcupine diets documented in the present study, comparative behavioural studies on the activity budgets of

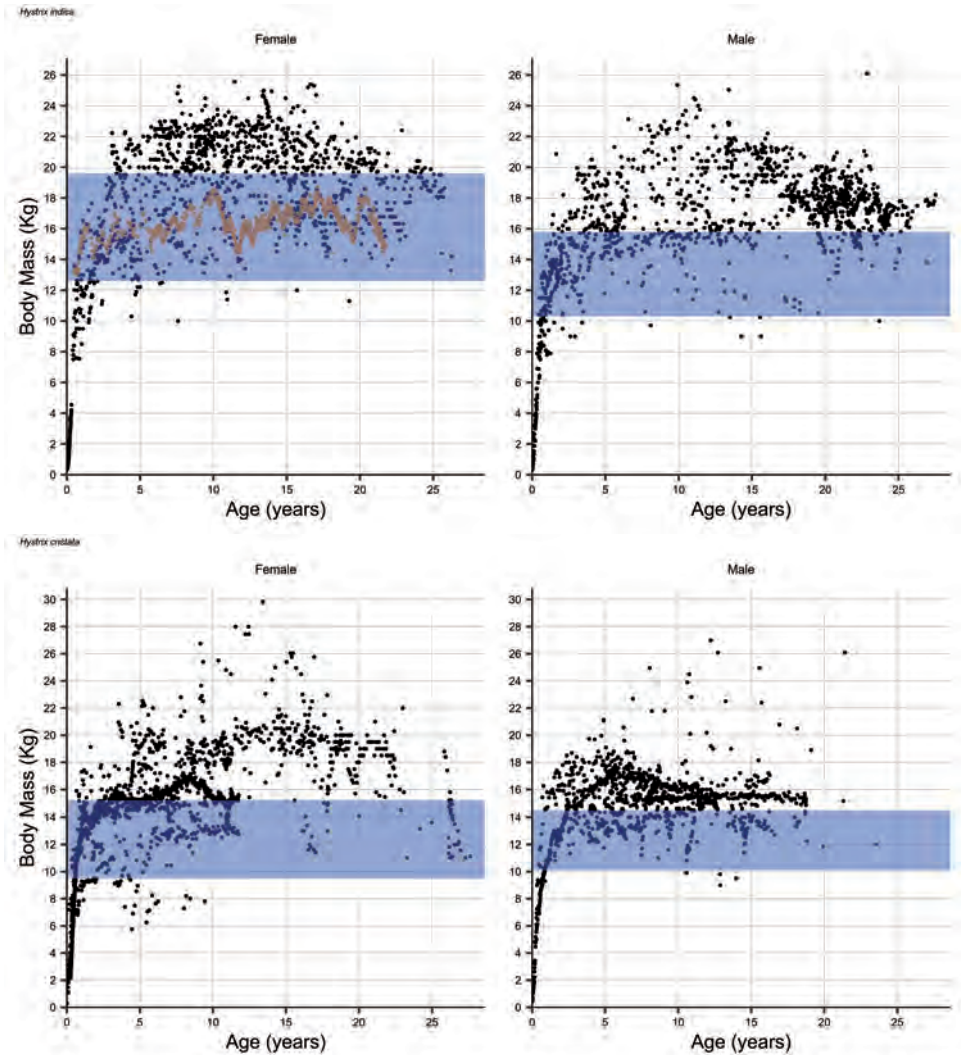


Fig. 7: Body mass in Indian crested porcupines (*Hystrix indica*; **A**) and African crested porcupines (*Hystrix cristata*; **B**) kept globally in zoos (black dots) compared to literature data for free-ranging specimens (blue bar; for details see table 5). Note that a large number of zoo individuals exceed the body mass range reported for free-ranging animals, and a fluctuating pattern suggestive of a seasonal pattern in a single *H. indica* female (orange dots)

Tabl. 3: Body mass records (in kg) for adult, free-ranging in Indian (*Hystrix indica*) and African crested porcupines (*Hystrix cristata*) in natural habitats.

Source	n	minimum	average	maximum
<i>Hystrix indica</i>				
<i>females</i>				
(Girish et al. 2006)	2	14.5	14.9	15.3
(Alkon et al. 1986)	1	-	17.8	-
(Alkon 1984)	6	12.6	16.8	19.6
<i>males</i>				
(Vishnugurubaran et al. 2021)	1	-	12.5	-
(Alkon 1984)	8	10.3	11.9	15.8
<i>unknown sex</i>				
(Sever and Mendelssohn 1991)	10	-	13.9	-
(Alkon and Saltz 1988a)	11	-	14.1	-
<i>Hystrix cristata</i>				
<i>females</i>				
(Pigozzi 1987a)	10	-	11.4	-
(Mori et al. 2015a)	30	-	11.6	-
(Mori et al. 2015a)	11	-	11.8	-
(Mori et al. 2015a)	4	9.5	11.8	14.0
(Mori et al. 2015a)	1	-	10.3	-
(Mori et al. 2015a)	1	-	14.5	-
(Angelici et al. 2009)	3	10	12.3	15
(Coppola et al. 2020d)	6	11.0	12.9	15.2
(Mori and Lovari 2014)	42	-	12.1	-
(Pigozzi 1987b)	9	-	11.1	-
(Sonnino 1998)	1	-	13.8	-
(Corsini et al. 1995)	1	-	13.8	-
<i>males</i>				
(Pigozzi 1987a)	14	-	10.1	-
(Mori et al. 2015a)	20	-	12.4	-
(Mori et al. 2015a)	27	-	11.3	-
(Mori et al. 2015a)	2	10.5	11.8	13.0
(Coppola et al. 2020d)	5	11.0	12.6	14.5
(Mori and Lovari 2014)	40	-	11.4	-
(Pigozzi 1987b)	8	-	10.2	-
(Sonnino 1998)	3	-	12.3	-
(Corsini et al. 1995)	3	11.5	12.4	13.5
<i>unknown sex</i>				
(Santini 1980)	n.g.	-	15	20

n.g. not given

porcupines under different feeding regimes would be highly feasible, including observations on the frequency of coprophagy.

Tab. 4: Body mass records (in kg) for adult Indian crested porcupines (*Hystrix indica*) and African crested porcupines (*Hystrix cristata*) under human care.

Source	n	minimum	average	maximum
<i>Hystrix indica</i>				
			<i>females</i>	
(Stalder et al. 2012)	10	9.5	11.3	13.1
this study	89	10.0	17.4 ±3.1 ^A	24.8
this study	89	10.0	17.4 ±3.1 ^A	24.8
			<i>males</i>	
(Švara et al. 2015)	1	-	14.5	-
(Stalder et al. 2012)	10	11.0	11.8	12.6
(Alkon et al. 1986)	4	14.7	16.1	18.1
this study	97	9.0	15.8 ±3.3 ^B	24.2
			<i>unknown sex</i>	
(Hagen et al. 2019)	3	13.1	16.1	18.1
<i>Hystrix cristata</i>				
			<i>females</i>	
this study	94	8.4	17.3 ±3.6 ^a	25.3
			<i>males</i>	
this study	54	9.4	16.1 ±3.3 ^b	26.5

A,B difference significant at $p = 0.001$

a,b difference tends towards significance at $p = 0.066$

Third, because voluntary intake of diet items that are highly palatable due to their energy density (e.g., the content of sugar or starch) will likely be higher than energetic requirements, higher growth rates and obesity are logical consequences of such diets (Prebble et al., 2015b, Glogowski et al., 2018). In their natural habitat, *H. indica* body mass averages at 16.5 kg for females and 12.0 kg for males, and that of *H. cristata* at 11.9 kg for females and 11.4 kg for males (Tab. 3). Body mass data published previously for *H. indica* under human care were within the range of free-ranging specimens (Tab. 4). However, the average body mass of the global zoo data for *H. indica* was 17.4 ± 3.1 kg for females and 15.8 ± 3.3 kg for males. For *H. cristata*, this was 17.3 ± 3.6 kg for females and 16.1 ± 3.3 kg for males. Thus, zoo animals often surpassed the body mass range reported for free-ranging specimens (Fig. 7); even though the body mass data are not directly linked to the individuals surveyed in the present study, these data thus support the suspicion that many of the diets reported in our survey might trigger obesity.

Hystrix spp. are adapted to a seasonal accretion of adipose tissue reserves that will contribute to surviving through the wintertime (Alkon et al., 1986). It has been suggested that species that evolved a seasonal metabolism including the build-up of adipose tissue stores are particularly susceptible to obesity in managed care (Mellor et al., 2020), which would mean that body mass management is important in porcupines. A single female *H. indica* showed a clear, life-long pattern of seasonal fluctuation (Fig. 7). Whether this pattern occurs more frequently in zoos was difficult to assess within the present dataset; in particular, it has been suggested that seasonal body mass fluctuations might only be evident in animals that are not obese (Gerstner et al., 2016). Given the ease with which porcupines can reportedly be trained, and the availability of platform scales onto which the animals could be easily guided using a target, it would be highly interesting in the future to document body mass across several seasons in porcupines that are not obese, and to directly

compare the body masses of porcupines in zoos under different feeding regimes. Additional, more data on free-ranging specimens would be welcome.

With respect to sexual size dimorphism, zoo data suggests a highly significant female-biased sexual size dimorphism for *H. indica* (Tab. 4) that corresponds to reports in the literature (Tohmé & Tohmeé, 1980; Alkon & Saltz, 1985). By contrast, the numerical difference between the sexes in *H. cristata* only tended towards significance in the zoo data (Tab. 4), similar to the criticism voiced by Mori & Lovari (2014) on the previous suggestion of Pigozzi (1987a) that this species also has a female-biased sexual size dimorphism.

The actual dietary requirements of porcupines are largely unknown. *Hystrix* spp. have been suggested to require UV-light induced vitamin D for a normal calcium metabolism, and this assumption has been used as an explanation for diurnal sunbathing behaviour in these generally nocturnal species (Coppola et al. 2019). However, the urine of a *Hystrix* ssp. was found to contain high levels of calcium (Haim et al. 1992b), suggesting that the calcium metabolism of these species is similar to that of lagomorphs and other hystricomorph rodents in that more calcium is absorbed from the digestive tract than necessary, and the surplus excreted in the urine (Hagen et al. 2015). It has been suggested that in such species, vitamin D may be of little relevance for calcium metabolism (Liesegang et al. 2024).

While 41% (n=24) of the zoos surveyed also feed animal products to porcupines, 59% (n=35) did not do so. The question of whether animal material should be fed to porcupines is also answered differently in legal requirements. Whereas the feeding of animal matter is not regulated in Germany and Switzerland, porcupines must receive bones with meat residues in Austria (Table 1). This discrepancy is also reflected in the scientific literature on the natural diets of crested porcupines: Table 5 summarises which publications have described their diets as containing or not containing bones, insects, flesh and hairs of animals. Because collecting and ingesting bones has been shown in both species (Duthie and Skinner 1986; Kadhim 1997; Kiibj 2009; O'Regan et al. 2011; Coppola et al. 2020c), it can be assumed that porcupines in the wild eat animal products when they are available. While this need not translate into a requirement of daily offerings of bones, the occasional provision of bones can likely be considered an imitation of the natural diet that can be used to structure the life of zoo porcupines beyond a daily rhythm.

Tab. 5: Overview of the animal components of the diet of free-ranging Indian (*Hystrix indica*) and African (*Hystrix cristata*) crested porcupines.

Author	Species	Animal product	Comments
Mori et al. (2021)	<i>H. cristata</i>	Insects	Only in February-March (during lactation)
Coppola et al. (2020c)	<i>H. cristata</i>	Meat	Scavenging behaviour recorded
Coppola and Felicoli (2021)	<i>H. cristata</i>	Bones	During reproduction
Kiibj (2009)	<i>H. cristata</i>	Bones	
Kaur et al. (2019)	<i>H. spp.</i>	Bones	
Akram et al. (2017)	<i>H. indica</i>	Bones, hairs of animals	5.6 – 6.4 % of the ratio, whole year round
Kadhim (1997)	<i>H. indica</i>	Insects, bones	
Bouaceur et al. (2024)	<i>H. cristata</i>	No animal matter	
Mori et al. (2017)	<i>H. cristata</i>	No animal matter	
Hafeez et al. (2011)	<i>H. indica</i>	No animal matter	
Khan et al. (2021)	<i>H. indica</i>	No animal matter	

Finally, the participating zoos did not use a variety of feeding methods to offer diet items to their porcupines. Given that porcupines often dig out their food in natural habitats (Shachak et al. 1991; Bragg et al. 2005), methods of feeding them in a way that they have to dig out diet items, e.g. in a larger area of relatively loose sand so that food is easy to hide, might be an interesting method of

using a natural behaviour. Again, behavioural studies on porcupines under a variety of methods of offering the same diet items would be a promising future study.

Conclusions

The variety of husbandry and feeding practices noted in our survey reflects the fact that no husbandry guidelines exist for these species. The typical limitations of a survey based on a questionnaire apply. Even though a large amount of data can be gathered in this way, very few conclusions about the effect of one parameter on another can be made. Hence, this study mainly serves as a status quo baseline that may be useful in the future to assess changes or progress in porcupine husbandry.

Indian and African crested porcupines are relatively easy to keep, and they rarely suffer from serious clinical diseases based on current observations under human care. Care must be taken with group composition to avoid intraspecific aggression. Since they are also familiar with temperatures around freezing in their natural habitat, they can easily have access to outdoor enclosures all year round in Central Europe. However, due to the animals' distinct ability to escape, these enclosures must be well protected against digging under, climbing over or biting through the fence. Following the natural diet of porcupines, their diet in human care should also consist largely of browse and branches, hay, grass and vegetables as well as high-fibre pellets. Animal products such as bones should also be provided on occasion. Due to their tendency to become obese, cultivated fruit, grain products and low-fibre pellets should not be used in human care, and cultivated tubers – although seemingly corresponding to the natural diet of tubers and roots – are also most likely higher in easily digestible carbohydrates than their uncultivated counterparts and should therefore not be used. Changes in routines, such as feeding in several small portions and at different locations or hiding the food, or destroying burrow structures at larger time intervals to stimulate digging, might improve health and well-being. Improvements in historical zoo survivorship likely indicate more engaged husbandry over time; this could be continued by producing husbandry guidelines for these species.

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Competing interests

The authors have no conflicts of interest.

Zusammenfassung

Indische Weißschwanzstachelschweine (*Hystrix indica*) und Gewöhnliche Stachelschweine (*Hystrix cristata*) sind beliebte Zootiere in Europa und werden insgesamt in rund 400 Einrichtungen gehalten. Ziel dieser Studie war es, die Haltings- und Fütterungsbedin-

gungen dieser beiden Stachelschweinarten in europäischen Zoos genauer zu untersuchen und häufige Krankheitsbilder zu erfassen. Zu diesem Zweck wurden Daten von 90 Zoos erhoben, die an der Studie teilnahmen. Im Durchschnitt wurden $3,8 \pm 2,7$ Stachelschweine pro Gehege gehalten, wobei die meisten Zoos (70 %) über ein kombiniertes Außen- und Innengehege verfügten. Die durchschnittliche Größe des Außengeheges betrug $164 \pm 196 \text{ m}^2$ und wurde durch ein durchschnittliches Innengehege von $14 \pm 18 \text{ m}^2$ ergänzt. Die gängigsten Methoden zur Populationskontrolle waren gleichgeschlechtliche Gruppen (39 %) und ein „Breed and Feed“-Regime (28 %). Nur 23 % der Zoos praktizierten ein medizinisches Training mit ihren Stachelschweinen. Obwohl Stachelschweine in menschlicher Obhut selten erkranken, gibt es einige typische Krankheitsbilder: 22 % ($n = 10$) aller klinischen Fälle in dieser Studie betrafen die Haut, wobei die Hälfte dieser Hauterkrankungen durch innerartliche Aggressionen verursacht wurde. Wahrscheinlich aufgrund der verbesserten Haltungsbedingungen in den letzten Jahren und der Fortschritte in der Zootiermedizin zeigte die gesamte europäische Zoopopulation beider Arten eine Verbesserung der historischen Überlebensrate in Zoos sowohl für adulte als auch für juvenile Tiere. Die durchschnittliche geschätzte Futterration der Stachelschweine bestand aus Gemüse, pelletiertem Kraftfutter, kultivierten Früchten (Obst), Samen und Getreideprodukten, Nüssen, tierischen Produkten und einer geschätzten Aufnahme von etwa 90 g Trockenmasse Heu oder Gras. Bei der Fütterung von Obst, pelletiertem Kraftfutter, Heu und tierischen Produkten gab es enorme Unterschiede: Elf Zoos fütterten ausdrücklich kein Obst, während in den übrigen Zoos der Anteil an Obst an der Gesamtration zwischen 0,7 und 48 % der gesamten Trockenmasse lag. Nur 56 % ($n = 33$) aller befragten Zoos fütterten ihren Stachelschweinen Heu, und in diesen Zoos war die durchschnittliche Menge an Nicht-Raufutter geringer, was darauf hindeutet, dass die Aufnahme von Heu mit einem geringeren Angebot anderer Futtermittel bewirkt werden kann. 20 % ($n=11$) der Zoos boten Nicht-Raufutter in Mengen an, die über der geschätzten Tagesaufnahme lagen, was zu der Annahme führt, dass ihre Tiere selbst bei Angebot kein Raufutter aufgenommen hätten. Die durchschnittliche Körpermasse von in Zoos gehaltenen *Hystrix* spp. war höher als die von freilebenden Exemplaren, was auf eine energiereiche, raufutterarme Ernährung in Zoos zurückzuführen sein könnte, die zu Fettleibigkeit führt. Daher sollten kein Obst, Getreideprodukte oder faserarme Pellets verwendet werden. Wir empfehlen, die Ernährung auf hochwertiges Grasheu als Grundfutter zu stützen und dieses durch frische Zweige, grünes Blattgemüse, begrenzte Mengen an angebauten Knollenfrüchten und mineralhaltige Pellets mit hohem Fasergehalt zu ergänzen, um eine angemessene Mineralstoffversorgung sicherzustellen. Zusammen mit unserer umfangreichen Literaturrecherche können die Ergebnisse dieser Studie als Grundlage für Haltungsrichtlinien für diese Arten dienen.

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Appendix I

Questionnaire (which was spread via surveymonkey)

1. Introduction

This survey was designed by Martin Polotzek (zoo director and veterinarian in Zoo Cleves, Germany [“Tiergarten Kleve”]) and Marcus Clauss (Vetsuisse University, Zurich) to create a comprehensive overview of husbandry conditions of Indian crested porcupines (*Hystrix indica*) and African crested porcupines (*Hystrix cristata*) in European zoos. Furthermore, the information obtained should be used to make best practice guidelines for husbandry, feeding and veterinary treatment.

2. About your Indian crested porcupines

Name and location of your zoo:

On 31st December 2021 how many Indian crested porcupines lived in your institution?

_____, _____, _____ (male, female, unknown)

Please give us an overview about your group structure and write the number of your animals in the following datasheet. Alternatively, you can send us your Indian crested porcupine-taxon report from ZIMS to polotzek@tiergarten-kleve.de.

Breeding animals	
Adults (>2 years; excl. breeding pair)	
Subadults (between 1 and 2 years)	
Juveniles (< 1 year)	

Are your Indian crested porcupines socialized with other animal species?

No

Yes, with: _____

If they are socialized with other species, do you see a negative aspect for one of the species?

No

Yes, if yes, please specify:

Do you have any veterinary problems resulting from association with other species?

No

Yes, following veterinary problems:

Why do you keep Indian crested porcupines? (Multiple selection possible)

Education

Research

High visitor attractiveness

Easy to keep

To revive a vacant enclosure

Low acquisition and maintenance costs

Other, please specify:

3. Enclosure

In which type of housing are your Indian crested porcupines kept?

Only indoor enclosure

Indoor and outdoor enclosure

Only outdoor enclosure without heated boxes

Only outdoor enclosure with heated boxes

To get an overview about your Indian crested porcupine enclosure, please give us the following information for the **outdoor** enclosure:

Seize:

Barrier height (at the lowest point):

Underground protection:

Ground:

Structure elements:

Which type of barriers are you using for your Indian crested porcupine enclosure: (Multiple selection possible)

Wire mesh

Glass

Cement wall

Wood wall

Electric fence

Trenches

Other: _____

To get an overview about your Indian crested porcupine enclosure, please give us the following information for the **indoor** enclosure:

Seize:

Temperature:

Separation possibility:

Ground/bedding:

Structure elements:

Did you have any breakout events in your porcupine enclosure? If yes, please specify?

4. Keeping

Which kind of contact do you practice with your Indian crested porcupines?

Direct contact (keepers and other staff members are at the same time in the same enclosure as the porcupines)

Indirect contact (the enclosure is entered only when the porcupines are locked away)

Do you practice medical training in Indian crested porcupines? (YES / NO)

If yes, which exercise(s) do you use? (Multiple selection possible)

Target training

Ultrasound training

Blood sample training

Mouth examination training

Other - please specify:

How do you catch your Indian crested porcupines? (Multiple selection possible)

Net

Drift board

Catch cage

Distance immobilization (blow pipe...)

Other – please specify:

Are there any special events with your Indian crested porcupines? (Multiple selection possible)

Behind-the-scenes tours

Meet the public

Public feeding/keepers talk

Other, please specify:

There is no special event with our porcupines.

Did you have any human injuries due to porcupine interaction? (YES / NO; if yes, please specify)

5. Nutrition

Please, send us your feeding instruction for Indian crested porcupines via email: polotzek@tiergarten-kleve.de.

Do you have any personal comments regarding Indian crested porcupine feeding that you want to share?

6. Veterinary medicine

Please, send us your Indian crested porcupine veterinary reports from the last 10 years to polotzek@tiergarten-kleve.de.

Do you use reproductive management other than placing offspring to other facilities in your Indian crested porcupines?

Chemical contraception (please, specify)

Breed and cull

Same-sex-groups

We don't use any of these management options in our porcupines.

Do you have any personal experiences or opinions you want to share on

Vaccination

Parasites and antiparasitic treatment

Specific diseases

Antibiotic treatment

Anesthesia and analgesia

7. Pathological findings

Please, send us your Indian crested porcupine pathological reports from the last 10 years to polotzek@tiergarten-kleve.de.

Do you have any personal comments regarding Indian crested porcupine pathology that you want to share?

Additional questions about nutrition which were send separately via email:

Do you feed pellets to your porcupines? If yes, which kind of feed pellets?

Do you feed hay to your porcupines?

Do you feed branches to your porcupines?

Do you feed animal products like bones or meat to your porcupines?

Appendix II

Drugs used in Indian crested porcupines (*Hystrix indica*) and African crested porcupine (*Hystrix cristata*). Information derived from ZIMS in italics

Drug name	Drug dose	Comments
Antimicrobials and Antifungals		
Amoxicillin	200 mg/animal SID IM	Pneumonia
Amoxicillin/clavulanic acid	140 mg/animal amoxicillin + 35 mg/animal clavulanic acid SID IM	Bronchopneumonia
Azithromycin	<i>10 mg/kg SID PO [1]</i>	
Cefalexin	<i>0.13-20 mg/kg BID PO [2]</i>	
Cefquinom		Topically in flushed abscess
Ceftriaxone	125 mg/animal SID IM x5d [19]	After abscess splitting
Doxycycline	<i>3-5 mg/kg BID PO [3]</i>	
Enrofloxacin	5-10 mg/kg SID IM or PO <i>5.5 mg/kg BID PO or 6.5 mg/kg SID PO [4]</i> <i>6.4 mg/kg SID SC [4]</i> <i>5.65 mg/kg BID PO [29]</i>	
Marbofloxacin	0.38-2 mg/kg SID PO <i>2.5 mg/kg SID PO [5]</i>	
Metronidazole	<i>19 mg/kg BID PO [6]</i>	
Streptomycin + penicillin	200,000 IE/animal penicillin + 200,000 IE/animal streptomycin SID SC	
Trimetoprim-Sulfodiazin	12-40 mg/kg BID PO	Skin conditions

Drug name	Drug dose	Comments
Anaesthesia		
Ketamine + medetomidine	3.8 mg/kg (K) + 0.06 mg/kg (M)	Antagonize with 0.3 mg/kg atipamezol
	<i>4 mg/kg (K) + 0.046 mg/kg (M) [20]</i>	<i>Abnormal recovery in 3.17 %</i>
	4.21 mg/kg (K) + 0.084 mg/kg (M) [30]	Shorter and calmer recovery compared to a combination of tiletamine-zolazepam with medetomidine
	6-10 mg/kg (K) + 0.01 mg/kg (M) [31]	
Ketamine + xylazine	3-4 mg/kg (K) + 0.03-0.04 mg/kg (M) [36, 37]	
	10.1 mg/kg (K) + 1.5 mg/kg (X)	Antagonize with 0.22 mg/kg atipamezol or 0.4 mg/kg yohimbine
	<i>11.73 mg/kg (K) + 1.64 mg/kg (X) [21]</i>	<i>Abnormal recovery in 3.45 %</i>
	15 mg/kg (K) + 1 mg/kg (X) [26; 27]	
	10 mg/kg (K) + 2 mg/kg (X) [33, 35]	
	5-10 mg/kg (K) + 1-2 mg/kg (X) IM [36, 37]	
Butorphanol + ketamine + medetomidine	300 mg (K) + 20 mg (X) IM per adult animal [38]	
	<i>0.3 mg/kg (B) + 4.18 mg/kg (K) + 0.06 mg/kg (M) [22]</i>	<i>Abnormal recovery in 4.17 %</i>
Dexmedetomidine + ketamine	<i>0.027 mg/kg (D) + 5.49 mg/kg (K) [23]</i>	
Ketamine + midazolam	3-4 mg/kg (K) + 0.03-0.04 mg/kg (M) IM, IV [37]	
Ketamine + acepromazine + hylase	5.5 mg/kg (K) + 0.25 mg/kg (A) + 7.5 IE/kg (H)	

Tiletamine-zolazepam	8.86 mg/kg [24]	<i>Abnormal recovery in 33.33 %</i>
	8.0 mg/kg [25]	
	4-8 mg/kg [32]	
	7.25 mg/kg [34]	
	4-6 mg/kg [36, 37]	

Tiletamine-zolazepam + medetomidine	3.7 mg/kg (TZ) + 0.0047 mg/kg (M) [30]	Longer and more restless recovery compared to a combination of tiletamine-zolazepam with medetomidine
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Propofol	6-8 mg/kg IV [36, 37]	
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Drug name

Drug dose

Comments

Sedatives and Tranquillizers

Acepromazine	0.1 mg/kg IM [36, 37]	
Diazepam	0.1-1.0 mg/kg IM, IP, PO [36, 37]	Unpredictable results and irritations during IM administration
Midazolam	0.1-0.5 mg/kg IM [36, 37]	Premedication with lower doses
Xylazine	1-5 mg/kg IM, SC [36, 37]	

Drug name

Drug dose

Comments

Analgesic

Buprenorphin	0.01-0.6 mg/kg SC once [7]	
	0.01-0.03 mg/kg IM, SC q8-12 h [36, 37]	
Butorphanol	0.5 mg/kg IM, SC q4h [36, 37]	
Carprofen	4 mg/kg SID PO	
	1.8-4.4 mg/kg SID PO [8]	

Flunixin	0.5 mg/kg IM, SC SID-BID [36, 37]	
Gabapentin	15 mg/kg BID <i>5 mg/kg SID PO or 9 mg/kg BID PO [9]</i>	
Ketoprofen	1-3 mg/kg IM, SC SID [36, 37]	
Meloxicam	0.2-1.25 SID PO or SC or IM <i>0.5 mg/kg SID PO [10]</i> <i>0.4 mg/kg SID IM [10]</i> <i>0.2 mg/kg SID PO [28]</i>	
Metamizol	0.1-0.3 mg/kg SC, PO SID-BID [36, 37]	
Morphine	37.5 mg/kg	
Oxymorphone	1-3 mg/kg IM, SC q4-6h [36, 37]	Usually used as a single dose before surgery
Piroxicam	0.1 mg/kg IM, SC q6-12h [36]	
Prednisolon	<i>0.4 mg/kg SID PO [11]</i>	
Tramadol	0.2 mg/kg SID PO	
	<i>6.6 mg/kg BID PO [12]</i>	
	0.5-5 mg/kg SID-BID PO [36]	

Drug name	Drug dose	Comments
Antiparasitic		
Fenbendazole	10 mg/kg SID PO x3d <i>21 mg/kg SID PO x5d [13]</i>	
Ivermectin	0,2-1.5 mg/kg SC or PO once 0.4 mg/kg PO three time q7d <i>0.2 mg/kg SC or PO once [14]</i>	

Selamectin 120 mg/animal topically

Drug name	Drug dose	Comments
Other		
Arnica montana Dil. C 30	2 ml/animal	After chemical castration
Atropine	0.03 mg/kg SC, IM [36, 37]	
Doxapram	0.5-6 mg/kg IM [15]	
Furosemide	2.4 mg/kg SID PO [16]	
Glycopyrrolate	0.01 mg/kg IM, SC [36, 37]	
Pentobarbital	90-400 mg/kg intracardiac [17]	Euthanasia
Pimobendan	0.23 mg/kg BID PO [18]	
Vitamin E-Selen	10 mg/juvenile animal vitamin E + 0,07 mg/juvenile animal selen SC	Young animal prophylaxis on day 4

Diagnosed bacteria by the participating zoos	Diagnosed fungi by the participating zoos	Diagnosed parasites by the participating zoos
<i>Acinetobacter dijksboorniae</i>	<i>Aspergillus fumigatus</i>	<i>Trichuris</i> sp.
<i>Bordetella bronchiseptica</i>		<i>Strongylidae</i>
<i>Clostridium sordelli</i>		<i>Giardia</i>
<i>Clostridium perfringens</i>		
<i>Lactobacillus</i> sp.		
<i>Lecleria adecarboxylata</i>		
<i>Pseudomonas</i> sp.		
<i>Psychrobacter</i> sp.		
<i>Raoultella</i> sp.		
<i>Streptococcus canis</i>		
<i>Streptococcus</i> sp.		
<i>Vibrio metschnikovii</i>		

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filters: Hystrix indica/Indian crested porcupine
- [2]: ZIMS Drug Usage Extracts for *Hystrix indica* and Cefalexin. (2022, September 06). Species360 Zoological Information Management System. Retrieved from <http://zims.Species360.org>
filters: Hystrix indica/Indian crested porcupine
- [3]: ZIMS Drug Usage Extracts for *Hystrix indica* and Doxycycline. (2022, September 06). Species360 Zoological Information Management System. Retrieved from <http://zims.Species360.org>
filters: Hystrix indica/Indian crested porcupine
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filters: Hystrix indica/Indian crested porcupine
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filters: Hystrix indica/Indian crested porcupine
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filters: Hystrix indica/Indian crested porcupine
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filters: Hystrix indica/Indian crested porcupine
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filters: Hystrix indica/Indian crested porcupine
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filters: Hystrix indica/Indian crested porcupine
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filters: Hystrix indica/Indian crested porcupine
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filters: Hystrix indica/Indian crested porcupine
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filters: Hystrix indica/Indian crested porcupine
- [15]: ZIMS Drug Usage Extracts for *Hystrix indica* and Doxapram. (2022, September 06). Species360 Zoological Information Management System. Retrieved from <http://zims.Species360.org>
filters: Hystrix indica/Indian crested porcupine
- [16]: ZIMS Drug Usage Extracts for *Hystrix indica* and Fursosemide. (2022, September 06). Species360 Zoological Information Management System. Retrieved from <http://zims.Species360.org>
filters: Hystrix indica/Indian crested porcupine

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filters: *Hystrix indica*/Indian crested porcupine
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filters: *Hystrix indica*/Indian crested porcupine
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filters: *Hystrix indica*/Indian crested porcupine
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filters: *Hystrix indica*/Indian crested porcupine
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filters: *Hystrix indica*/Indian crested porcupine
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filters: *Hystrix cristata*/Crested porcupine
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Appendix III

Infectious agents diagnosed in Indian crested porcupines (*Hystrix indica*) and African crested porcupines (*Hystrix cristata*) by the participating zoos

Diagnosed bacteria by the participating zoos	Diagnosed fungi by the participating zoos	Diagnosed parasites by the participating zoos
<i>Acinetobacter dijksboorniae</i>	<i>Aspergillus fumigatus</i>	<i>Trichuris</i> sp.
<i>Bordetella bronchiseptica</i>		<i>Strongylidae</i>
<i>Clostridium sordelli</i>		<i>Giardia</i>
<i>Clostridium perfringens</i>		
<i>Lactobacillus</i> sp.		
<i>Leceria adecarboxylata</i>		
<i>Pseudomonas</i> sp.		
<i>Psychrobacter</i> sp.		
<i>Raoultella</i> sp.		
<i>Streptococcus canis</i>		
<i>Streptococcus</i> sp.		
<i>Vibrio metschnikovii</i>		