Parasitology Research (2023) 122:3181–3188
https://doi.org/10.1007/s00436-023-08009-9

RESEARCH

Sarcoptes scabiei infestation in a captive lowland tapir (*Tapirus terrestris*): case report, morphological and molecular genetic mite identification

Perrine Keiser[1,2] · Christoph Hörweg[3] · Anna Kübber-Heiss[4] · Stephan Hering-Hagenbeck[5] · Bita Shahi-Barogh[2] · Katharina Reitl[1] · Hanna Vielgrader[1] · Thomas Voracek[1] · Hans-Peter Fuehrer[2] · David Ebmer[1]

Received: 29 July 2023 / Accepted: 10 October 2023 / Published online: 26 October 2023

Abstract
Sarcoptes scabiei (Acari: Sarcoptidae) is a globally distributed parasitic mite species, which causes mange in a broad spectrum of domestic and wild mammals. In the present study, we report a case of chronic *S. scabiei* infestation in a captive lowland tapir (*Tapirus terrestris*) held in a multi-species exhibit at Vienna Zoo. The adult male showed clinically manifested mange flare-ups three times at an interval of up to 12 months, diagnosed by positive deep-skin scrapings and successfully treated by oral applications of ivermectin (0.1–0.2 mg/kg body weight) and washings with antimicrobial solutions. Clinical symptoms including pruritus, alopecia, erythema, crusts, and superficial bleedings were limited to the axillar and pectoral region, as well as distal limbs. The affected tapir died from underlying bacterial pneumonia during general anesthesia. Skin scrapings, necropsy, and histopathological analysis of mite material (eggs, larvae, and adults) permitted further morphological and molecular identification. The morphological features described here matched the characteristics for the species *S. scabiei* and molecular data verified morphological identification. Cross-species transmission plays a key role in the expansion of this neglected emerging panzootic disease and urban wildlife could potentially bridge the gap between free-ranging wildlife reservoirs and zoo animals. However, further examinations are needed to detect the primary source of infestation and discover transmission pathways within the zoo.

Keywords Sarcoptic mange · Zoological garden · Wildlife · Tapir

Introduction

Sarcoptes scabiei (De Geer, 1778) is a globally distributed ectoparasitic mite species within the family Sarcoptidae with a complex taxonomy and it is classified as the only species within the genus and divided into different varieties (Zhang 2011). *Sarcoptes scabiei* constitutes the causative agent for scabies (by *S. scabiei* var. *hominis*) and pseudoscabies in humans, and sarcoptic mange in various domestic and wildlife mammalian hosts (Bornstein et al. 2001; Moroni et al. 2022). Listed by the World Health Organization as a neglected tropical skin disease of humans (WHO 2022) and an important emerging infectious disease in wildlife (Tompkins et al. 2015), the ubiquitous mite is considered to have one of the largest host spectra among parasites with at least 148 different reported host species (Currier et al. 2011; Escobar et al. 2022).

Sarcoptes mites spread mostly by direct contact. Nevertheless, indirect contact plays a role, but depends on the

Section Editor: Julia Walochnik

✉ Hans-Peter Fuehrer
Hans-Peter.Fuehrer@vetmeduni.ac.at

✉ David Ebmer
d.ebmer@zoodoc.at

1 Veterinary Clinic Vienna Zoo, Seckendorff-Gudent-Weg 6, 1130 Vienna, Austria

2 Institute of Parasitology, Department of Pathobiology, University of Veterinary Medicine Vienna, Veterinaerplatz 1, 1210 Vienna, Austria

3 3rd Zoological Department, Natural History Museum Vienna, Burgring 7, 1010 Vienna, Austria

4 Research Institute of Wildlife Ecology, Department of Interdisciplinary Life Sciences, University of Veterinary Medicine Vienna, Savoyenstr. 1, 1160 Vienna, Austria

5 Vienna Zoo, Maxingstr. 13b, 1130 Vienna, Austria

mites' survival capacities off the host and therefore on environmental conditions, seasonality, and host ecology (Escobar et al. 2022). Adult mites reproduce on the hosts' skin, where eggs are laid into the stratum spinosum and one larval and two nymphal stages (proto- and tritonymphs) dwell there until spreading at adult stage (Kutzer and Grünberg 1967; Arlian and Morgan 2017). Adult mites parasitize the epidermis, where they burrow tunnels through the skin's surface to the *stratum granulosum*, feeding on live skin cells and organic fluid, triggering a popular dermatitis. The resulting strong pruritus then typically provokes localized alopecia, inflammation associated erythema, extensive hyperkeratosis, as well as superficial skin lesions inflicted by self-traumatizing through scratching, biting, and rubbing, often followed by secondary bacterial pyodermia (Kutzer and Grünberg 1967; Bornstein et al. 2001; Pence and Ueckermann 2002). Severely affected hosts can display apathy, dehydration, and emaciation, which may even lead to death (Pence and Ueckermann 2002).

Sarcoptic mange has been frequently reported in numerous free-ranging mammalian species, where it can develop from limited periodic outbreaks to extensive epizootics in naive populations (Tompkins et al. 2015; Gonzalez-Astudillo et al. 2018). Outbreaks with a mortality rate of at least 70% have been reported in Spanish ibex (*Capra pyrenaica*), Northern chamois (*Rupicapra rupicapra*), red foxes (*Vulpes vulpes*), grey wolves (*Canis lupus*), and common wombats (*Vombatus ursinus*) (Pence and Ueckermann 2002; Escobar et al. 2022), which led to population declines and potentially putting already threatened species even more at risk of extinction (Pedersen et al. 2007). However, despite modern non-invasive wildlife monitoring methods such as camera trapping, infrared thermal imaging, detector dogs, and citizen science, data on disease prevalence is generally scarce and mostly only available after outbreaks (Lange et al. 2014). Therefore, it is essential to identify reservoir wildlife species with high transmission capacity, eventually through asymptomatic carriers, which are in contact with endangered species, as well as to implement more extensive disease monitoring programs and control strategies across taxa and geographic ranges (Escobar et al. 2022).

Close contact between wildlife, domestic animals, and humans is a common and ever recurring pattern in recorded mange outbreaks in wildlife as well as spillover events across species. Human-domestic-wildlife animal interfaces allow for such close interactions in which domestic animals—usually widely distributed and kept in high densities, such as dogs (*Canis lupus familiaris*)—tend to spread the disease, as so-called "bridge hosts," which connect the different interfaces (Pedersen et al. 2007; Poo-Muñoz et al. 2016). Therefore, the role of pets and livestock as reservoir and key spreading agents must not be underestimated, and they must be kept in mind as sentinels for human public health, as well as potential conservation threat for endangered wildlife species (Werner and Nunn 2020; Escobar et al. 2022). As shown in recent studies, sarcoptic mange has increased in severity, host range, and geographic spread, and could be considered an emerging panzootic and a threat for wildlife and biodiversity conservation (Gortázar et al. 2007; Tompkins et al. 2015; Escobar et al. 2022).

In contrast, only a few cases of sarcoptic mange have comprehensively been described in zoological institutions so far, ranging from captive maras (*Dolichotis patagonum)* (Kim et al. 2015) to ungulates kept in multispecies exhibits (Yeruham et al. 1996), leaving host origin and transmission pathways to zoo animals yet to be uncovered. Reported cases of infested tapirs with clinical manifestation are scarce, whether in captivity or in the wild. Kutzer and Grünberg (1967) described for the first time an infestation of four captive lowland tapirs *(Tapirus terrestris)*.

In the present study, we describe a case of chronic mange caused by *S. scabiei* in a captive lowland tapir held at Vienna Zoo. Thereby, we report diagnostic and treatment procedures, as well as pathological findings and morphological and molecular mite identifications.

Material and methods

Animal history

The herein presented 23-year old male lowland tapir was born at a zoo facility in Hungary. Since 2010, the male lived in a multispecies exhibit together with giant anteaters (*Myrmecophaga tridactyla*), vicunas (*Lama vicugna*), capybaras (*Hydrochoerus hydrochaeris*), rheas (*Rhea americana*), and seriemas (*Cariama cristata*) and another male lowland tapir. The enclosure consisted of an inside stall building containing a pond and resting place with hay and straw bedding, as well as an outside area with meadows, trees, and a larger pond supplied by two small watercourses. The two tapirs had permanent access to the external enclosure. None of them was neutered or chemically castrated, nor had any of them received treatment against ectoparasites before.

Medical history

In February 2018, the tapir presented skin alterations on the cheeks and the chest for the first time, which resolved themselves. In May 2019, a submandibular abscess distal to the tongue's base was punctured and drained under general anesthesia. Samples for bacteriological cultures were taken. Three months later, the abscess reoccurred in the same localization.

In November 2019, the animal presented moderate hyperkeratosis, alopecia, and skin inflammation symptoms associated with minor bleedings on the pectoral and axillar region as well as laterodistally on all four limbs, suspected to be resulting from irritation through repeated scratching and rubbing (Fig. 1). Local therapy by debridement and cleaning of the lesions with chlorhexidine-based products ensued, followed by a deep skin scraping of all the lesions for parasitological as well as mycological screening. However, the pruritus and alopecia on the pectoral region reoccurred 3 months later, and deep skin scrapings were performed again.

Erythema, pink-reddish-colored skin areas and crusts, appeared almost a year later, followed by deep skin scrapings. In March 2021, a new submandibular abscess in the same localization as the two previous ones was diagnosed. Later on, the animal developed dyspnoea, cough associated with erythema and mucus in the trachea. The male subsequently died during general anesthesia in October 2021 after a respiratory arrest and unsuccessful resuscitation. Neither the second lowland tapir nor any of the other mammals sharing the same exhibit displayed any clinical symptoms coherent with dermatological issues during that time.

Morphological ectoparasite identification

Deep skin scrapings were taken three times, in November 2019, February 2020, and January 2021 after the appearance of pruritus associated typical skin lesions on the following sites: laterodistally on all four limbs and on the pectoral region. Skin scrapings were also obtained from the second lowland tapir, as well as from the other mammals in the exhibit such as capybaras, giant anteaters, and vicunas. The scraped skin material was microscopically examined after dissolution in 10% potassium hydroxide (KOH) solution.

Molecular identification

DNA was extracted from mite eggs using the Qiagen DNeasy Blood and Tissue kit (Qiagen, Hilden, Germany). Samples were incubated at 56 °C overnight and processed according to the manufacturer's protocol.

Conventional polymerase chain reactions (PCRs), targeting the barcode region within the mitochondrial cytochrome c oxidase subunit I gene (COI), using primers Lep-F1: 5′-ATTCAACCAATCATAAA- 3′ and Lep-R1: 5′-TAAACT TCTGGATGTCCAAAAA–3′ (Hebert et al. 2004) as well

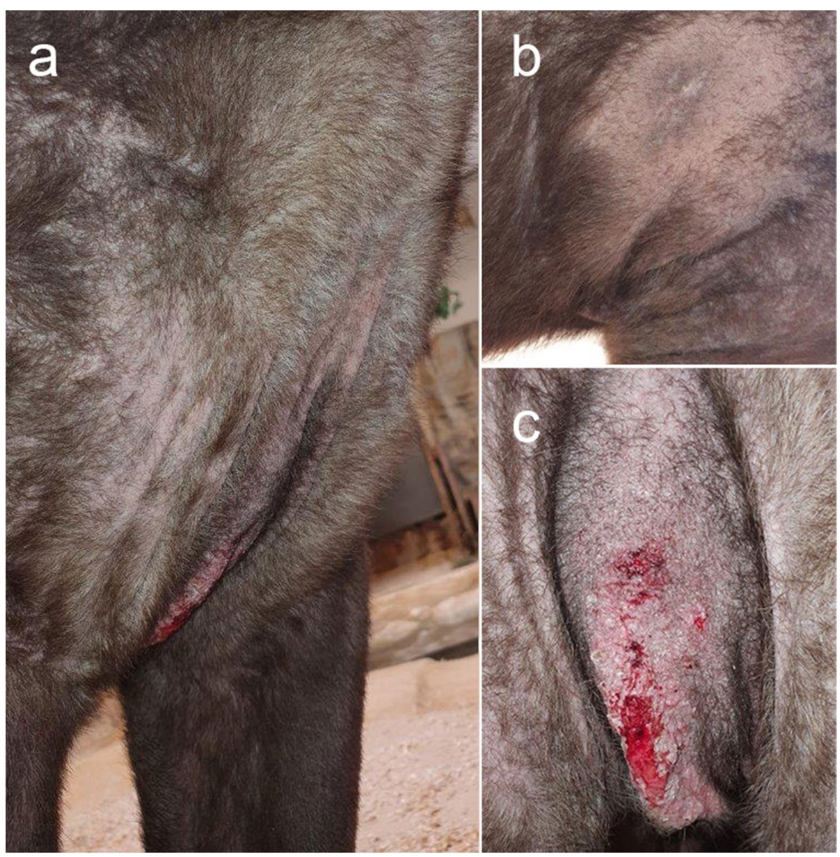

Fig. 1 Clinical presentation of a lowland tapir (*Tapirus terrestris)* with pectoral and axillary alopecia and superficial sternal skin abrasions sternally (first appearance of symptoms). **a** General view of cutaneous lesions and local alopecia on chest area. **b** Localized restricted alopecia of chest region. **c** Cutaneous abrasions associated with superficial minor bleedings and alopecia in fronto-pectoral region

as within the 16S gene Demo16s_for: 5′-GAG GTA TTT TGA CTG TGC TA-3′ and Demo16s_rev 5′-TCA AAA GCC AAC ATC G-3′ (Zhao and Wu 2012),

SSUDF: 5′-GGGTCTTTTTGTCTTGGAATAAA-3′ and SSUDR: 5′-CTAAGGTAGCGAAATCATTAGC-3′ (Angelone-Alasaad et al. 2015) gave negative results. Specific *S. scabiei* primers *S. scabiei cox1F*: 5′CTGGTAGAG GAACTGGCTG3′ and *S. scabiei cox1R*: 5′GTAAACTTC CGGGTGTCC3′ to amplify a ~ 374 bp fragment of the cox1 gene were used as reported previously (Fraser et al. 2018).

The reaction volume was 50 µl containing 5 µl of genomic DNA template, standard PCR buffer (5xGreen GoTaq® Reaction Buffer, Promega USA), 25 mM of each dNTP, 1.25 U of Taq polymerase (GoTaq® G2 DNA Polymerase, Promega, USA), and 10 pmol of each oligonucleotide primer. Mite samples which gave negative results were additionally screened with a high-fidelity polymerase using the GoTaq® Long PCR Master Mix (Promega, Madison, USA). The cycling conditions were identical to those for the conventional nested PCR.

PCR products were analyzed by electrophoresis on 2% agarose gels stained with Midori Green Advance (Nippon Genetics Europe, Germany). Positive samples were sent for sequencing (LGC Genomics GmbH, Germany) and further analyzed with the software BioEdit v.7.2.5 and blasted to sequences deposited in GenBank® (BLAST: Basic Local Alignment Search Tool 2023). Resulting sequences were uploaded to GenBank®.

Post mortem examinations

Necropsy was performed immediately after death. Tissue samples from altered lung areas, lymph nodes, spleen, kidneys, and gastronintestinal tract were collected for pathohistology. Swabs from the trachea and lungs were taken for bacteriological examination. Skin samples and the gastronintestinal tract were screened for parasites.

Results

Clinical presentation

Bacteriological cultures of tissue material collected from the first submandibular abscess via puncturing (in May 2019) revealed the presence of *Corynebacterium* spp., *Fusobacterium* spp., and other anaerobic bacteria.

The deep skin scrapings from the four limbs with sternal localized alopecia and superficial skin abrasions (Fig. 1) were positive for *S. scabiei* mites under direct microscopic examination but tested negative for fungi. Systemic treatment with ivermectin 0.1 mg/kg SID per os for a week repeated after 2 weeks resulted in the disappearance of clinical symptoms.

Following the reoccurrence of pruritus and alopecia 3 months later, deep skin scrapings were performed again; however, no mites could be detected.

Almost a year later, the tapir displayed erythema and crusts again, which led to highly positive deep skin scrapings for mite eggs and larvae. Systemic therapy with ivermectin 0.2 mg/kg SID per os was implemented for 3 cycles of one week each, separated by a two-week interval. Already after the first therapy cycle a decrease of the clinical symptoms was noted.

In March 2021, a reoccurring submandibular abscess in the exact same localization as the two previous ones was diagnosed and drained under general anesthesia. *Pseudomonas* spp. and *Rahnella aquatilis* were isolated by bacteriological culture.

None of the affected tapir's cohabitants in the same enclosure tested positive for *S. scabiei* by deep skin scrapings.

Morphological identification and analysis

The mites detected by deep-skin scraping were examined under light microscopy and identified as *S. scabiei* (Acari: Sarcoptidae) (Fig. 2), according to morphological characteristics (Fain 1968; Arlian and Morgan 2017). Adults and tritonymphs, as well as larvae and eggs, were isolated under stereomicroscopy (Fig. 2a). The adult and subadult stages displayed a round to oval-shaped idiosoma, which was not protruded by the leg pairs III and IV at its caudal margin, as typical for Sarcoptidae. Long setae on the tarsus of both these leg pairs were visible in females, while only on leg III in males (Fig. 2b). In contrast to the hind limbs, legs I and II however typically extend over the idiosoma's cranial margin and both terminate in empodia and pads in both females and males (Fig. 2b). Additionally, the adult and subadult mites also showed the characteristic triangular cuticular spines, short setae as well as fine striations on the dorsal idiosoma (Fig. 2b, c). Even a single egg in a fertilized female mite could be also observed (Fig. 2d).

Molecular genetic identification

Two mites gave positive results at PCR and were sequenced successfully (GenBank: OQ746463). Obtained sequences were 99.7% identical to *S. scabiei* parasitizing Koala (Australia, MF083743), wombats (Australia, MF083741), vicugna (Argentinia, OL739584), dog (China, KJ748528), *S. scabiei* type *suis* in pigs (Australia, LN874270), and *S. scabiei* type *hominis* in humans (Australia, LN874268; Saudi Arabia: OK310847).

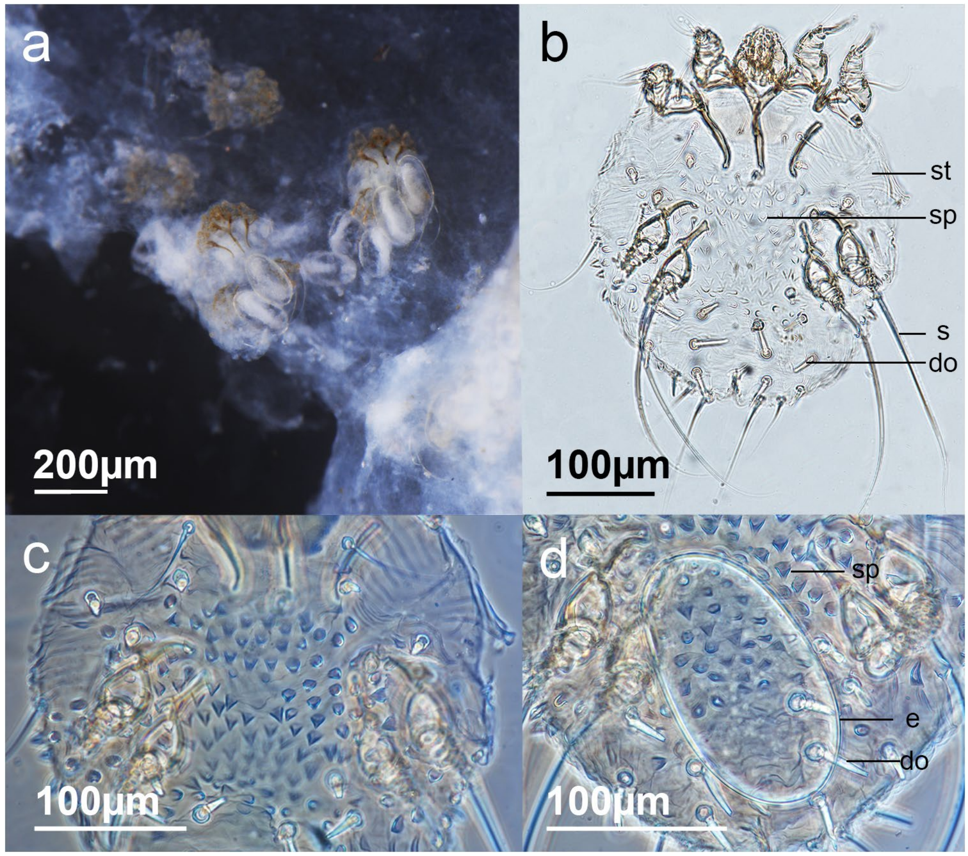

Fig. 2 Morphological mite identification of *Sarcoptes scabiei*. **a** Stereo micrographs of mites. **b** Light microscopic images of adult *S. scabiei*, showing cuticular spines (sp), stout dorsal setae (do), and coarse striations (st), as well as long setae (s) on the tarsus of legs III and IV. **c** View of cuticular spines. **d** Intraabdominal egg (**e**) in a female *S. scabiei*

Pathological findings

The tapir was in moderate body condition and weighed 177.5 kg. On gross pathology the skin on the lower thorax and inner side of the front limbs showed crusts and scales with elder erosion signs on the chest. Histologically, focal purulent scab and discreet skin inflammation associated with epidermal erosion were noted. Furthermore, burrowing mites were visible in histological slices from pectoral regions in cross and sagital section inside of tunnels in the stratum corneum (Fig. 3a). Their gnathosoma including the short chelicerae and pedipalps were visible in crossection (Fig. 3b), as well the characteristic triangular cuticular spines of *S. scabiei* on the dorsal idiosoma (Fig. 3c).

Furthermore, a severe chronic purulent and granulomatous pneumonia could be determined. The tapir was diagnosed with chronic sarcoptic mange and bacterial pneumonia.

Discussion

We here describe a rare clinical case of sarcoptic mange in an adult male captive lowland tapir (*T. terrestris*), and we provide clinical and pathological data and morphological and molecular mite identifications. Case reports in the genus *Tapirus* are rare, whether in captivity or in the wild (Kutzer and Grünberg 1967; Frolka 1986; Żuchowska 1991).

The clinical symptoms in the tapir were similar to typical signs occuring in canids, wombats, and ibexes (Pence and Ueckermann 2002). However, in the tapir, the alopecic lesions did not extent to the dorsal and facial region, but instead were limited to distal and axillar region of the limbs, hinting toward a disease diagnosis at early disease development stage which prevented further spreading and increasing severity of skin lesions. Differentials would include dermatophytosis, secondary bacterial pyodermia, yeast overgrowth such as *Malassezia* dermatitis, as well as non-infectious causes such as food allergy and atopic dermatitis, and less commonly neoplastic skin diseases.

Kutzer and Grünberg (1967) described cases of severe sarcoptic mange in juvenile and adult captive lowland tapirs with extensive skin lesions and alopecia progressively covering all of the back including neck and forehead, as well as limbs specifically at joint regions. The symptoms displayed in those hosts were similar to our case, but accompanied in the juvenile individual by a general debilitation and severe bacterial bronchopneumonia due to *Streptococcus* spp. leading to its death. Although the here described tapir did not present such strong clinical signs and extensive lesions, the

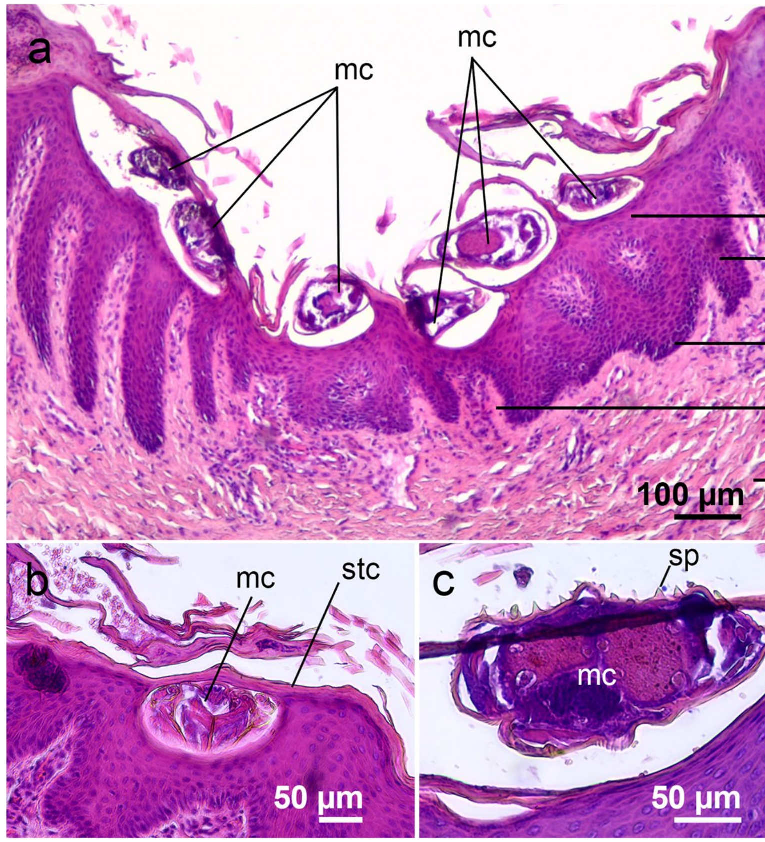

Fig. 3 Histologic section of the pectoral region from the lowland tapir showing epidermal erosion associated with burrowing *Sarcoptes scabiei*. **a** Cross-section of several mites (mc) burrowed in tunnels excavated through the *stratum corneum* (stc) of the epidermis into the *stratum granulosum* (SG), leaving the deeper skin layers seemingly undeteriorated: *stratum spinosum* (SS); *stratum basale* (SB); *stratum papillare* (SP); *stratum reticularis* (SR). **b** Cross-section of the proximal idiosoma of a single mite (mc) showing its stout gnathosoma with chelicerae and pedipalps. **c** Cross-section of a single mite (mc) showing internal organs and cuticular spines (sp)

alterations of the general health state included, besides the mange flare ups, recurring abscesses and bacterial pneumonia, that was associated as cause of death. Nevertheless the course of disease might also have been influenced by induced stress or other unknown stress factors.

In the current case, the transmission pathway of *S. scabiei* remains to be determined. Despite none of the other taxa in the same exhibit displayed any clinical manifestation or positive skin-scrapings, asymptomatic carriers among the giant anteaters (*M. tridactyla*), vicunas (*L. vicugna*), capybaras (*H. hydrochaeris*), or the second lowland tapir still may come into question in transmitting the mites through direct contact or shared housings. Interestingly, all of these mentioned animal species have previously been reported as hosts for *S. scabiei* (Żuchowska 1991; Gomez-Puerta et al. 2013; Nowak 2015; Berger et al. 2017). The same is true for urban wildlife such as rodents, hedgehogs, stray cats, martens, or red foxes crossing through the zoo and its outdoor enclosures. As habitat fragmentation and green space reduction in urban areas force wildlife to increasingly interact with pets or captive zoo species (Rentería-Solís et al. 2014), the risk of cross-species transmission of ectoparasites can increase as well. Sarcoptic mange in red foxes was mentioned in the eastern region of Austria (Prosl et al. 2001), and during routine veterinary work, we observed clearly infested wild red foxes in the surroundings of the zoo in the past. In the future, crossing wildlife should therefore be thoroughly investigated. Another possible pathway constitutes mother-to-pup transmission through very close skin-to-skin contact for a prolonged time during rearing with asymptomatic to minor symptomatic episodes until the detection of clinical cases at Vienna Zoo.

Through the use of molecular tools such as microsatellite markers newer findings suggest that spatial distribution (Matsuyama et al. 2019; Escobar et al. 2022) rather than than the previously considered strictly taxon-oriented patterns, also known as host-taxon law (Rasero et al. 2010), might come into play in interspecies transmission. Tranmission among "broad taxa" might be more strongly related to sharing a similar ecological niche in a common geographical area (Moroni et al. 2023), enabling direct as well as indirect contact between different species. In the tapir's case, the prey-to-predator approach (Gakuya et al. 2011) can be excluded; however, a common spatial distribution factor seems more likely to have been key in spreading mites putatively from urban wildlife onto the captive tapir rather than per an exclusive host species-related pathway. However, a singular case does not permit generalisation for a whole genus and more case studies are needed for clarification.

Regular screenings of the mammal species in the same enclosure and of crossing mamalian urban wildlife by skin-scrapings and serological ELISA assays (Arlian and Morgan

2017) could have revealed asymptomatic carriers or previously infected individuals and thereby helped to identify the original transmitting host.

Zoonotic potential should be considered, however, restricted to a self-limiting clinical dermal inflammation associated with pruritus and papule formation known as pseudoscabies (generated by short-time dwelling of mites in the epidermis unable to burrow tunnels or reproduce) (Deplazes et al. 2020). In the present case, a spillover event and cross-species transmission could potentially have happened involving zookeepers and veterinarians, who interacted closely with the infected animal on a daily basis. However, no such events have been observed by the zoo keepers, as additional hygiene measures were implemented during that time.

Conclusion

This is one of a few single reported cases of *S. scabiei* in a captive lowland tapir (*T. terrestris*). The mode of transmission remains unclear, as cases are still rarely documented in zoos and the infection status of free-ranging tapir populations is difficult to determine. Following up on such uncommon cases in zoological facilities should be seen as an opportunity to investigate the dynamics of interspecies transmissions across urban wildlife and captive exotic species, which could help our understanding of the transmission mechanism on larger scales in wildlife populations. This is particularly relevant with regards to sarcoptic mange as one of many threats to endangered species.

Acknowledgements We gratefully acknowledge the assistance of Alexander Keller (Vienna Zoo) during sample-collection process (animal handling, skin scrapings). We would like to thank Regina Kramer and Iris Starnberger (Vienna Zoo) for the accurate review of the final version of the manuscript.

Author contribution Conceptualization: David Ebmer and Perrine Keiser; clinical work: Katharina Reitl, Hanna Vielgrader, Thomas Voracek, and David Ebmer; morphological analysis: David Ebmer and Christoph Hörweg; necropsy: Anna Kübber-Heiss; molecular analysis: Bita Shahi Barogh and Hans-Peter Fuehrer; writing—original draft preparation: Perrine Keiser and David Ebmer; writing—review and editing: Perrine Keiser, David Ebmer, Hans-Peter Fuehrer, and Christoph Hörweg; funding acquisition: Thomas Voracek and Stephan Hering-Hagenbeck. All authors read and approved the final draft of the manuscript.

Data availability The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval The Vienna Zoo approved the preparation of the present case report (TGS2022/1009) and the publication of the study.

Consent to participate Not applicable.

Consent for publication Not applicable.

Competing interests The authors declare no competing interests.

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