Journal of
Zoological and Botanical Gardens

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Review

Hedgehogs in Contact with Humans: Zoonotic and Reverse Zoonotic Transmission of Pathogens

Dražen Đuričić and Maja Lukač *

Department of Poultry Diseases with Clinic, Faculty of Veterinary Medicine University of Zagreb, Heinzelova 55, 10000 Zagreb, Croatia; ddjuricic@vef.unizg.hr
* Correspondence: maja.lukac@vef.unizg.hr

Abstract: Numerous previous studies indicate that both wild hedgehogs and those kept as pets pose a significant risk to human health. At the same time, humans can also transmit various pathogens to hedgehogs (e.g., human herpesvirus 1). The risk of human infection from hedgehogs by various bacteria, viruses, fungi, rickettsiae, and parasites, and of hedgehog infection from humans, arises from close contact with pet hedgehogs, wild hedgehogs, and/or the contaminated environment which they cohabit with humans. People can also come into close contact with hedgehogs in city parks, rescue and rehabilitation centers, gardens, suburbs, and zoos. Numerous zoos keep different species of hedgehogs, which are often used for education and interaction with visitors, especially children. In spite of certain preventive measures, periodic examinations, and disease controls being carried out, the possibility of the transmission of infectious diseases from hedgehogs to visitors and employees is not excluded. Close contact poses a risk, especially if biosecurity is not properly maintained. The anthropological effects of coexistence, habitat sharing, and frequent human intrusion into hedgehog habitats have disrupted the natural relationship between humans and animals, and have led to an increase in the prevalence of various pathogens. Although many different pathogens have been isolated in hedgehogs, there is a need to study some of them in more detail and to understand their interaction and transmission possibilities, as well as zoonotic and reverse zoonotic pathogens.

Keywords: hedgehogs; bacterial zoonoses; fungal zoonoses; viral zoonoses; parasitic zoonoses; reverse zoonoses

Academic Editor: Mariana Panayotova-Pencheva

Received: 25 November 2024
Revised: 7 February 2025
Accepted: 19 February 2025
Published: 3 March 2025

Citation: Đuričić, D.; Lukač, M. Hedgehogs in Contact with Humans: Zoonotic and Reverse Zoonotic Transmission of Pathogens. *J. Zool. Bot. Gard.* **2025**, *6*, 15. https://doi.org/10.3390/jzbg6010015

1. Introduction

The occurrence of disease in human populations may be enhanced by increased contact between humans and wild animals, as a result of human intrusion into wilderness areas, the intrusion of wild animals into areas of human activity, and human contact with different exotic species as pets. Humans can come into contact with hedgehogs in parks, rescue centers, gardens, and zoos, as well as other places where humans and hedgehogs cross paths, which can pose a significant health problem for both parties. Risk reduction is possible through continued education, public awareness, health surveillance, the early detection of disease, the implementation of biosecurity measures, and the monitoring of wildlife and exotic pets.

Hedgehogs are small, omnivorous, and nocturnal mammals of the order Eulipotyphla of the family Erinaceidae (subfamily Erinaceinae); the dorsal part of their skin is completely covered with spines. Based on the shape and pattern of the spines, the length of the ears, and the appearance of the skull, the 18 species are divided into five genera (*Erinaceus*,

Atelerix, *Hemiechinus*, *Paraechinus*, and *Mesechinus*), which are distributed worldwide (including Europe, Africa, and Asia; they have also been introduced in New Zealand and America) [1]. The most popular species to keep as a pet is the four-toed or African pygmy hedgehog (*Atelerix albiventris*).

In certain rural, urban, and suburban areas, the coexistence of hedgehogs and humans has increased the prevalence of various pathogens with zoonotic potential, necessitating an assessment of the importance of these animals as potential carriers of zoonotic diseases, as well as the possibility of transmission of various pathogens from humans to hedgehogs [2]. In addition to hedgehogs from the wild, growing importance is also being attached to African pygmy hedgehogs, which, along with numerous other exotic animals, are increasingly common pets in our homes.

In some Western European countries, the number of European hedgehogs is declining significantly [3] due to a number of factors, including the disappearance, destruction, and fragmentation of natural habitats, the isolation of small hedgehog populations, the consequences of low genetic diversity, increased mortality due to pollution, poisoning (rodenticides, limacides, etc.) [4], and the risk of road traffic injuries [5], a reduction in invertebrate prey, and interspecific competition and predation (e.g., Eurasian badger (*Meles meles*) [6]), among others [7]. Parts of cities and suburbs contain gardens, parks, and greenery where hedgehogs can hide from predators and find shelter and food sources [8]. People come into contact with wild hedgehogs by taking them into their homes, caring for sick animals, returning them to the wild, and/or in animal rescue and rehabilitation centers. Many people put food for their spiny visitors in the garden or parks, which prolongs their activity during the winter and delays their hibernation, but also encourages inter- and intraspecies competition and aggression because the food attracts them to the same place [8,9]. Using their feces and other excreta, hedgehogs can also contaminate the environments in which people and their pets (dogs and cats) exist; these excreta can also serve as mechanical carriers of certain diseases.

European hedgehogs are an important link for the survival and transmission of various diseases transmitted from ticks to humans, in urban and suburban areas [10], during walking, resting, or recreation in parks and gardens [11]. In order to reduce the risk of infectious and invasive diseases that hedgehogs can transmit to humans (and vice versa), it is necessary to avoid direct contact with animals and contact with environments contaminated by hedgehog excrement, and it is mandatory to wear protective gloves (especially when handling individuals from the wild) and to practice hand washing after every interaction with pet hedgehogs or wild hedgehogs [2,12]. African pygmy hedgehogs, when kept as pets, should be kept in an adequate and clean space, while sick and suspicious animals should be separated immediately and owners should seek professional veterinary help.

In many zoos, there are numerous educational programs for preschool and school children, as well as for high school students and students of natural sciences, biology, and animal health; visits to zoos are usually carried out in line with nature and biology lessons that explain the role of zoos in modern society. During these visits, particularly during education about and interactions with hedgehogs, the risk of transmission of infectious and parasitic diseases is present, as described in the cases of wild hedgehogs or pet hedgehogs [13].

2. Parasitic Zoonotic Pathogens

In relation to other pathogens that can be found in hedgehogs, we can state that parasites have the least zoonotic significance compared to bacteria, viruses, and fungi. Parasites are organisms that feed for a long period of time at the expense of the host, and are divided, according to the location of parasitism, into external (ectoparasites) and internal

(endoparasites) parasites [14]. Ectoparasites are frequent causes of skin diseases in the African pygmy hedgehog, but also in the European hedgehog. In the wild, different species of hedgehogs are often infested by ticks, fleas and mites, while, in captivity, infestation by fleas and ticks is very rare [15].

However, hedgehogs can transmit some endoparasites to humans, such as the protozoan *Cryptosporidium* sp., which poses a threat to public health due to the possibility of waterborne transmission. The zoonotic potential is present and appropriate precautions should be taken to avoid contamination and prevent transmission to humans, namely thorough hand washing with soap and water after handling hedgehogs and the use of disposable gloves. Intestinal cryptosporidiosis was the cause of death of a young African pygmy hedgehog living in captivity [16]. During a serosurvey of European hedgehogs, in addition to antibodies against Q fever and ornithosis, antibodies against the protozoan *Toxoplasma gondii* (the causative agent of toxoplasmosis) were also found; therefore, hedgehogs should also be considered as a potential risk for infection [17,18].

Only one case of giardiasis, a disease caused by a protozoan from the genus *Giardia*, has been recorded in European hedgehogs: hedgehogs on one farm in New Zealand were infected by a worker suffering from giardiasis. Although this is a zoonosis, it is possible to transfer parasites from humans to animals, in this case to hedgehogs, and vice versa [19].

The lungworm *Eucoleus aerophilus*, in addition to parasitizing hedgehogs, can invade wild carnivores and occasionally humans. There is a risk to human health because people can become infected by ingesting lungworm eggs found on contaminated surfaces [20].

3. Bacterial Zoonotic Pathogens

As hedgehogs can serve as reservoirs for and sources of *Salmonella* spp. in humans [21], salmonellosis is the most common zoonotic bacterial disease in hedgehogs. The causative agent is a Gram-negative, anaerobic, facultative, and rod-shaped bacterium from the genus *Salmonella* (family Enterobacteriaceae). In highly developed countries, pet hedgehogs are a source of infection for *Salmonella* serovar *tilene* [22]. The most common type of salmonella that causes infections in humans and animals is *Salmonella enterica* serovar *enteritidis* [21], but *S. typhimurium* has also been found in samples from both pets and wild hedgehogs [23–25]. Among the clinical signs of *S. typhimurium* in hedgehogs, anorexia, weight loss, and diarrhea prevail. Numerous human cases of salmonellosis associated with direct contact with hedgehogs have been described worldwide [22–26]. In addition to direct contact, another source of infection in humans is the excrement of a wild hedgehog contaminating water sources and the rest of the environment through which hedgehogs pass. A number of strict biosecurity measures, along with mandatory proper handwashing after every instance of contact with hedgehogs, can significantly reduce the risk of salmonellosis.

Leptospirosis is an acute, septicemic infectious disease in domestic and wild animals, as well as humans, which is caused by mobile spirally coiled bacteria from the genus *Leptospira* (family Leptospiraceae). The species *L. interrogans* is representative of all pathogenic leptospires, and it is divided, according to its antigenic properties, into twenty serological groups, each with a dozen or more serovars. Different types of *Leptospira* spp. have been isolated, with prevalences ranging from 7 to 37%, from wild hedgehogs in Europe (*L. interrogans*, *L. borgpetersenii*, and *L. ballum*) [27] and from the Amur hedgehog in Asia (*Erinaceus amurensis*) (*L. interrogans*) [28] and in New Zealand (*L. ballum*) [29]. Hedgehogs can be potential carriers of these bacteria as, after bacteremia, leptospira enter the kidneys and are excreted in the urine, as in other animals that then become reservoirs, such as rodents [30].

In clinically healthy European hedgehogs from the wild, in addition to salmonella and leptospira, other pathogenic bacteria have been isolated, including the following:

Anaplasma phagocytophilum, *Borrelia burgdorferi sensu lato*, *Borrelia miyamotoi* [31], *Coxiella burnetii* [32], *Rickettsia helvetica*, *Mycobacterium avium*, *Mycobacterium bovis*, *Staphylococcus aureus*, methicillin-resistant *S. aureus* (MRSA) [33], and *Streptococcus pyogenes*. In pet hedgehogs, the following pathogenic bacteria have been isolated: *Corynebacterium* sp., *Mycobacterium marinum*, *Salmonella stanley*, *Salmonella tilene* [17,30], and *Streptococcus dysgalactiae* [34].

Methicillin-resistant *Staphylococcus aureus* (MRSA) is resistant to most β-lactams and is an increasingly frequent cause of nosocomial infections in humans worldwide [35,36]; it has also been isolated from hedgehogs. Specifically, different strains of MRSA have been isolated from wild hedgehogs in Europe. A study conducted in New Zealand showed an 85% prevalence of *S. aureus* in hedgehogs with a high rate of penicillin resistance (86.3%). Monecke et al. [28] found fatal septicemia in two hedgehogs infected with MRSA, and severe dermatitis in another hedgehog. Bengtsson et al. [33] isolated MRSA in 64% of wild hedgehogs in their sample in Sweden using nasal, oral, and perineal swabs. The prevalence of MRSA in European hedgehogs in Denmark was found to be 61%, but the zoonotic transmission of MRSA was not confirmed [36].

Mycobacteria are Gram-positive, acid-resistant bacteria that cause several infectious diseases in humans and animals (including tuberculosis and paratuberculosis). In New Zealand, in an endemic area for bovine tuberculosis, wild hedgehogs play a significant role in the transmission of this disease [37]; *Mycobacterium bovis* has been isolated from 5.1% and *M. avium* from 1.3% of hedgehogs. In addition to the causative agent of tuberculosis and paratuberculosis in cattle, *Mycobacterium marinum* has also been found in Japan in African pygmy hedgehogs (*Atelerix albiventris*) and in European hedgehogs, which are kept as pets [38,39].

In urban and suburban areas, it is very likely that European hedgehogs contribute significantly to the spread and transmission of tick-borne pathogens, as relatively high prevalences of *Borrelia burgdorferi*, *B. bavariensis*, *B. spielmanii*, *B. afzelii*, *Borrelia miyamotoi*, *A. phagocytophilum*, and *R. helvetica* in the tick hosts *Ixodes ricinus* and *Pholeoixodes hexagonus* (formerly *Ixodes hexagonus*) have been found [40].

Coxiella burnetii are obligate, intracellular, Gram-negative bacteria that cause Q fever. Domestic and wild animals are considered reservoirs and/or carriers of these pathogens. People can become infected by direct contact with infected animals or their secretions (urine, feces, milk, and amniotic fluid), but also through hematophagous vectors (e.g., ticks). The high prevalence of *C. burnetii* in Amur hedgehogs in the Hubei province of China, measuring 12.2%, is because, in that region of central China, people eat hedgehogs, but hedgehog products are also used to treat hemorrhoids, according to traditional Chinese medicine [32]. When catching, slaughtering, or preparing food or medicine from hedgehogs, people can become infected with the causative agent of Q fever, both due to direct contact and after inhaling a contaminated aerosol.

Borreliosis (or Lyme disease) is one of the most widespread bacterial diseases in humans that is transmitted by ticks in Europe. These spiral bacteria are related to leptospires, and belong to the *Borrelia burgdorferi* (*sensu lato*) complex, which consists of several different genotypes (*B. burgdorferi*, *B. afzelii*, *B. garinii*, *B. spielmanii*, and *B. bavariensis*) [41]. The pathogen is transmitted by scrub ticks (fam. Ixodidae) from the genus *Ixodes* (e.g., *I. ricinus*) [42]. Early clinical signs may appear within a month of infection as small, red bumps around the tick bite site. After a few days, the redness can spread and form a specific rash (erythema migrans), which is mostly warm to the touch, not painful, and not itchy. Other signs are flu-like (e.g., fever, fatigue, body aches, headache, and, later, the enlargement of the lymph nodes). If untreated, the disease becomes chronic; it can last for months and years and can cause severe arthritis and neurological symptoms (e.g., meningitis, temporary facial paralysis, numbness and fatigue, difficulty moving, headaches, and many

others). Neurological disorders can be caused by *B. garinii*, which is transmitted by birds, and *Borrelia bavariensis*, which is often found in rodents and hedgehogs. *Borrelia spielmanii* infection is rare in humans, and the reservoir hosts are from the family Gliridae and hedgehogs [41,42]. In addition to the aforementioned *Borrelia* species, in ticks taken from hedgehogs, *Borrelia miyamotoi* has also been found [40]. Gene sequencing determined three different genospecies of *B. burgdorferi* in *E. europaeus*; the most common was *B. afzelii*, followed by *B. bavariensis* and *B. spielmanii*, with the latter being discovered for the first time in Germany (Hamburg), while *B. afzelii* and *B. bavariensis* were also found in *E. roumanicus*. The prevalence of *B. burgdorferi* in *E. europaeus* can range from 0 to 37.5% (i.e., in the Czech Republic), and, for the species *E. roumanicus*, it can range from 0 to 50.0% (i.e., in Austria) [41].

4. Fungal Zoonotic Pathogens

The most common fungal skin infection transmitted by hedgehogs to humans is caused by the hedgehog dermatophyte *Trichophyton erinacei*. Numerous cases of *T. erinacei* ringworm infection in humans have been described after contact with pets or wild hedgehogs [43–47]. European hedgehogs, as well as four-toed hedgehogs (along with other hedgehog species), are carriers of *T. erinacei*. Clinical signs characteristic of *T. erinacei* infection in hedgehogs include scabby lesions, alopecia, and the loss of spines. Fungal transmission from hedgehogs to humans can occur after just a few minutes of direct contact. The most common symptoms in humans occur on the wrist and hands, as well as on other areas of direct contact with the hedgehog, and include inflammation with itching, a rash, and the reddening of the skin [46,47]. The changes can sometimes disappear spontaneously 2 to 3 weeks after the appearance. At first, the symptoms are mild, but they intensify over time. Sometimes the initial rash resembles eczema, leading to misdiagnosis and the unnecessary use of corticosteroids, which can accelerate the progression of the infection and worsen the patient's condition [47]. It was previously thought that *Caparinia tripilis* mites could transmit ringworms from one animal to another, but it is now known that suckling young are already infected by their mother. In Europe, the prevalence of infection with *T. erinacei* (in a smaller number of tested animals) was approximately 30–50% [48,49], and in New Zealand, about 45% of the samples were positive [50].

Trichophyton erinacei has been isolated in clinically healthy hedgehogs from the wild along with the yeast *Candida albicans*; these have also been found in pet hedgehogs, as well as *Microsporum* spp., which is assumed to be transmitted from dogs and cats.

5. Viral Zoonotic Pathogens

The virus severe fever with thrombocytopenia syndrome (SFTSV) is the causative agent of hemorrhagic fever with thrombocytopenia syndrome, which affects humans and cats, and belongs to the genus *Banyangvirus* (family Phenuiviridae). This virus is transmitted by ticks among different species of wild and domestic animals in China, Japan, Korea, Vietnam, and Taiwan [51–53]. Hedgehogs produce antibodies and may serve as potential hosts, as approximately 64% of serum samples in one study were found to be positive for SFTSV, but are most likely not permanently infected [54].

The causative agent of tick-borne encephalitis (TBE) is a virus (TBEV) that causes fatal neurological infection in humans, involving tick hosts and wild vertebrates in Europe and Asia [47]. TBEV has been isolated from hibernating hedgehogs, so they are considered possible long-term reservoirs [55,56].

Several different viruses, such as Coronaviruses s (e.g., Erinaceus betacoronavirus—EriCoVs) and Bellerina (Paramyxovirusis) viruses have been widely isolated from various

species of hedgehogs in many countries, but their zoonotic potential has not been fully determined [57,58].

Crimean–Congo hemorrhagic fever is a zoonotic and often fatal disease seen in the Middle East, Eastern Europe, and Asia that is transmitted through the blood or tissue of infected animals and humans or through tick bites. The African pygmy hedgehog is susceptible to Crimean–Congo hemorrhagic fever, but its role in disease transmission is unknown [59].

The only recorded case of rabies in a hedgehog was in Hungary, when a family found a hedgehog in the city, which later died [60]. Although there are still many unknowns, numerous virological and molecular studies are underway throughout the world in order to specify the role of hedgehogs in the transmission of certain viruses to humans.

6. Reverse Zoonotic Potential

In addition to the fact that hedgehogs can be a potential source of infection and may transmit diseases to humans, humans can also be a source of various pathogens that can cause disease in hedgehogs. The importance of veterinary public health and the role of hedgehogs as potential carriers of zoonotic agents is, however, more significant than the reverse zoonotic potential of hedgehogs.

Streptococcus pyogenes is a Gram-positive, facultative, and anaerobic bacteria. Only one case of a death of a European hedgehog that suffered from streptococcal gingivitis and tooth root abscess has been reported [61], with the assumption that the hedgehog was infected by its owner.

Hedgehogs that are in close contact with humans, especially in parks, gardens, rescue centers, and zoos, could be at risk of contracting human diseases, especially those transmitted via the respiratory or fecal–oral route, such as influenza or COVID-19.

Human alphaherpesvirus-1 was isolated from the liver of a sick African pygmy hedgehog, and the owner was assumed to have been the source of infection for the hedgehog. The hedgehog died 2 weeks after infection with clinical signs of acute posterior paresis. It is not known whether the hedgehog should have been considered a blind host or a possible carrier of this virus [62]. Human alphaherpesvirus-1 also infects and can cause hepatitis and meningoencephalitis in Western European hedgehogs kept in captivity (there have been a few cases in wildlife treatment and rehabilitation facilities), where there was an opportunity for close contact with humans, which is unlikely for hedgehogs in the wild. People working with this species should practice good hygiene and biosecurity measures, as in other similar institutions [63]. The presence of a novel coronavirus (CoV) in hedgehogs in an urban area in Poland has been recorded. Hedgehog coronavirus 1 may pose a potential risk to humans because this newly discovered strain can recombine with other CoVs, which may lead to the emergence of new viruses with the potential for cross-species transmission [64]. Also, recently, in Germany, France, Great Britain, China, and Italy, coronaviruses associated with Middle East respiratory syndrome (MERS) have been discovered in hedgehogs, from which it follows that they could represent a wild reservoir of this virus [57,65].

7. Discussion

Zoonotic and reverse zoonotic risk in parks, rescue centers, gardens, zoos, and other places where the paths of humans and hedgehogs cross, can represent a significant health problem for both groups. The emergence of new zoonotic pathogens in the human population is contributed to by increased contact between humans and wild animals [66], as a result of human encroachment into wilderness areas or the entry of wild animals into areas of human activity. There are different methods of disease transmission from animals to humans, including direct (contact, excretions, etc.) or indirect (objects, contaminated surfaces, etc.)

transmission and transmission by an intermediate species (vector) that carries the causative agent of the disease without becoming ill (vector-borne diseases) [40–42]. Zoonoses can also be transmitted by consuming animals and products of animal origin [32].

In zoos, gardens, wildlife rescue centers, or parks where hedgehogs are often in contact with people, the risk of zoonotic transmission increases [67–69]. Visitors may touch or feed the hedgehogs, leading to the direct or indirect transmission of pathogens. Zoos and parks often keep different animal species in concentrated groups and close proximity, so hedgehogs in such environments may be at risk of exposure to diseases from other animals. In addition, human interaction in closed spaces can cause stress in hedgehogs, which weakens their immune system and potentially increases their susceptibility to infection. Risk mitigation is possible through education, raising public awareness, monitoring health, and applying biosecurity measures. Education on the importance of hygiene, such as wearing protective gloves, washing hands properly after handling hedgehogs, or avoiding direct contact with animals and their feces, is crucial. Also, the spread of pathogens can be reduced by applying protocols for cleaning and disinfecting enclosures in zoos and parks. Wildlife surveillance is extremely important and monitoring the health of hedgehogs in their environments can help in the early detection of disease.

Hedgehogs are key vectors of many zoonotic pathogens, including the most numerous bacterial species (*Salmonella* sp. [21–26], *Mycobacterium* sp. [37–39], methicillin-resistant *Staphylococcus aureus* [35,36], *Leptospira* sp. [27–30], Borellia [31,32,40–42], and others). Fungal pathogenic species follow in frequency (*Trichphyton erinacei*, *Microsporum*, and *Candida*) [43–50], followed by viral pathogens (tick-borne encephalitis virus (TBEV) [55,56], severe fever with thrombocytopenia syndrome virus (SFTSV) [51–54], and newly discovered CoVs related to MERS) in wild hedgehogs [64,65].

In relation to other pathogens that can be found in hedgehogs, we can state that parasites have the least zoonotic significance compared to bacteria, viruses, and fungi. The hedgehog flea, *Archaeopsylla erinacei*, has dermatopathological potential, but also acts as a vector for microorganisms responsible for numerous infectious diseases. It is known that these fleas can be accidental parasites in humans and that they can accidentally infect humans and transmit some diseases [69,70]. Ectoparasites are common in hedgehogs in the wild, but flea and tick infestations are very rare in captivity [70,71]. However, hedgehogs can transmit some endoparasites to humans. Among protozoa, members of the genus *Cryptosporidium* sp. [16,19], *Giardia* sp., and *Toxoplasma gondii* [18] have zoonotic potential. Although giardiasis is a zoonosis, the transmission of the parasite from humans to animals is also possible [19]. Some nematodes (e.g., lungworms—*Eucoleus aerophilus*), in addition to parasitizing hedgehogs, can be found in wild carnivores and occasionally humans through surfaces contaminated with their eggs [20].

The diseases that can be transmitted to hedgehogs by humans are the least common, compared to the diversity and frequency of zoonoses that can be transmitted from hedgehogs to humans. Therefore, the reverse zoonotic potential of hedgehogs is less significant than their zoonotic potential [67]. The role of humans was questionable in a single case of the infection of a hedgehog with the bacterium *Streptococcus pyogenes* [54,61]. Cases of infection with human alphaherpesvirus-1, which can cause hepatitis and meningoencephalitis, have been recorded in hedgehogs kept in captivity (namely, several cases in wildlife rehabilitation centers). The exact incidence of influenza or COVID-19 in cases of infection of hedgehogs from people with whom they have been in close contact, whether in parks, rescue or rehabilitation centers, gardens, or zoos, is not known.

8. Conclusions

Many different causative agents of diseases have been isolated from hedgehogs, not only from wild hedgehogs but also from hedgehogs in parks, playgrounds, zoos, and rescue centers, as well as from pet hedgehogs that cohabit with people. In conclusion, although there is a risk of zoonotic transmission and reverse zoonosis in parks, gardens, and zoos involving hedgehogs, the likelihood of these events can be reduced through effective biosecurity measures, management, surveillance, and education.

9. Future Directions

It is necessary to investigate in more detail the causes of parasitic, bacterial, viral, and fungal diseases and to determine the interaction and possibilities of transmission, as well as to determine the exact role of hedgehogs and their zoonotic and reverse zoonotic potential.

Author Contributions: Conceptualization, D.Đ. and M.L.; original draft preparation, D.Đ., writing—review and editing, D.Đ. and M.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Myers, P.; Espinosa, R.; Parr, C.S.; Jones, T.; Hammond, G.S.; Dewey, T.A. The Animal Diversity Web (Online). 2024. Available online: https://animaldiversity.org (accessed on 13 November 2024).
2. Ruszkowski, J.J.; Hetman, M.; Turlewicz-Podbielska, H.; Pomorska-Mól, M. Hedgehogs as a Potential Source of Zoonotic Pathogens—A Review and an Update of Knowledge. *Animals* **2021**, *11*, 1754. [CrossRef] [PubMed]
3. Taucher, A.L.; Gloor, S.; Dietrich, A.; Geiger, M.; Hegglin, D.; Bontadina, F. Decline in Distribution and Abundance: Ur-ban Hedgehogs under Pressure. *Animals* **2020**, *10*, 1606. [CrossRef]
4. Williams, E.J.; Cotter, S.C.; Soulsbury, C.D. Consumption of Rodenticide Baits by Invertebrates as a Potential Route into the Diet of Insectivores. *Animals* **2023**, *13*, 3873. [CrossRef] [PubMed]
5. Huijser, M.P.; Bergers, P.J.M. The effect of roads and traffic on hedgehog (*Erinaceus europaeus*) populations. *Biol. Conserv.* **2000**, *95*, 111–116. [CrossRef]
6. van de Poel, J.L.; Dekker, J.; van Langevelde, F. Dutch hedgehogs Erinaceus europaeus are nowadays mainly found in urban areas, possibly due to the negative effects of badgers Meles meles. *Wildl. Biol.* **2015**, *21*, 51–55. [CrossRef]
7. Holsbeek, L.; Rodts, J.; Muyldermans, S. Hedgehog and other animal traffic victims in Belgium: Results of a country-wide survey. *Lutra* **1999**, *42*, 111–119.
8. Reeve, N.; Berger, A.; Rasmussen, S.L. Applied Hedgehog Conservation Research. *Animals* **2024**, *14*, 976. [CrossRef]
9. Scott, D.M.; Fowler, R.; Sanglas, A.; Tolhurst, B.A. Garden Scraps: Agonistic Interactions between Hedgehogs and Sympatric Mammals in Urban Gardens. *Animals* **2023**, *13*, 590. [CrossRef]
10. Jota Baptista, C.; Oliveira, P.A.; Gonzalo-Orden, J.M.; Seixas, F. Do urban hedgehogs (*Erinaceus europaeus*) represent a relevant source of zoonotic diseases? *Pathogens* **2023**, *12*, 268. [CrossRef]
11. Benkacimi, L.; Diarra, A.Z.; Bompar, J.M.; Bérenger, J.M.; Parola, P. Microorganisms associated with hedgehog arthro-pods. *Parasit. Vectors* **2023**, *16*, 211. [CrossRef]
12. Krawczyk, A.I.; van Leeuwen, A.D.; Jacobs-Reitsma, W.; Wijnands, L.M.; Bouw, E.; Jahfari, S.; van Hoek, A.H.; van der Giessen, J.W.; Roelfsema, J.H.; Kroes, M.; et al. Presence of zoonotic agents in engorged ticks and hedgehog faeces from Erinaceus europaeus in (sub) urban areas. *Parasit. Vectors* **2015**, *8*, 210. [CrossRef] [PubMed]
13. Weese, J.S.; McCarthy, L.; Mossop, M.; Martin, H.; Lefebvre, S. Observation of Practices at Petting Zoos and the Potential Im-pact on Zoonotic Disease Transmission. *Clin. Infect. Dis.* **2007**, *45*, 10–15. Available online: https://www.jstor.org/stable/4464098 (accessed on 13 November 2024). [CrossRef] [PubMed]
14. Bowman, D.D. *Georgis' Parasitology for Veterinarians*, 7th ed.; W.B. Saunders Company: Philadelphia, PA, USA, 2021; pp. 1–285.
15. Dudek, K.; Foldvari, G.; Majlathova, V.; Majlath, I.; Rigo, K.; Molnar, V.; Toth, M.; Jankowiak, L.; Tryjanowski, P. Patterns in the Distribution and Directional Asymmetry of Fleas Living on the Northern White-Breasted Hedgehog Erinaceus roumanicus. *Folia Parasitol.* **2017**, *64*, 2026. [CrossRef]

16. Graczyk, T.K.; Cranfield, M.R.; Dunning, C.; Strandberg, J.D. Fatal cryptosporidiosis in a juvenile captive African hedgehog (*Ateletrix albiventris*). *J. Parasitol.* **1998**, *84*, 178–180. [CrossRef]
17. Riley, P.Y.; Chomel, B.B. Hedgehog Zoonoses. *Emerg. Infect. Dis.* **2005**, *11*, 1–5. [CrossRef]
18. Hofmannová, L.; Juránková, J. Survey of *Toxoplasma gondii* and *Trichinella* spp. in hedgehogs living in proximity to urban areas in the Czech Republic. *Parasitol. Res.* **2019**, *118*, 711–714. [CrossRef]
19. Hunter, P.R.; Thompson, R.C.A. The Zoonotic Transmission of Giardia and Cryptosporidium. *Int. J. Parasitol.* **2005**, *35*, 1181–1190. [CrossRef] [PubMed]
20. Traversa, D.; Di Cesare, A.; Lia, R.P.; Castagna, G.; Meloni, S.; Heine, J.; Strube, K.; Milillo, P.; Otranto, D.; Meckes, O.; et al. New insights into morphological and biological features of *Capillaria aerophila* (Trichocephalida, Trichuridae). *Parasitol. Res.* **2011**, *109*, 97–104. [CrossRef]
21. Lawson, B.; Franklinos, L.H.; Fernandez, J.R.R.; Wend-Hansen, C.; Nair, S.; Macgregor, S.K.; John, S.K.; Pizzi, R.; Nunez, A.; Ashton, P.M.; et al. Salmonella Enteritidis ST183: Emerging and endemic bio-types affecting western European hedgehogs (*Erinaceus europaeus*) and people in Great Britain. *Sci. Rep.* **2018**, *8*, 2449. [CrossRef]
22. Craig, C.; Styliadis, S.; Woodward, D.; Werker, D. African pygmy hedgehog–associated Salmonella Tilene in Canada. *Can. Commun. Dis. Rep. Relev. Mal. Transm. Can.* **1997**, *23*, 129–132.
23. Kagambèga, A.; Lienemann, T.; Aulu, L.; Traoré, A.S.; Barro, N.; Siitonen, A.; Haukka, K. Prevalence and characterization of Salmonella enterica from the feces of cattle, poultry, swine and hedgehogs in Burkina Faso and their comparison to hu-man Salmonella isolates. *BMC Microbiol.* **2013**, *13*, 253. [CrossRef] [PubMed]
24. Marsden-Haug, N.; Meyer, S.; Bidol, S.A.; Schmitz, J.; Culpepper, W.; Behravesh, C.B.; Morris, J.; Anderson, T.C. Multistate Outbreak of Human Salmonella Typhimurium Infections Linked to Contact with Pet Hedgehogs—United States, 2011–2013. *Morb. Mortal. Wkly. Rep.* **2013**, *62*, 73.
25. Ichimi, R.; Yoshino, A.; Higashigawa, M. Salmonella Stanley bacteremia transmitted from a pet hedgehog. *Pediatr. Int.* **2018**, *60*, 606–607. [CrossRef]
26. Handeland, K.; Refsum, T.; Johansen, B.S.; Holstad, G.; Knutsen, G.; Solberg, I.; Schulze, J.; Kapperud, G. Prevalence of Salmonella Typhimurium infection in Norwegian hedgehog populations associated with two human disease outbreaks. *Epidemiol. Infect.* **2002**, *128*, 523–527. [CrossRef] [PubMed]
27. Ayral, F.; Djelouadji, Z.; Raton, V.; Zilber, A.L.; Gasqui, P.; Faure, E.; Baurier, E.; Vourc'h, G.; Kodjo, A.; Combes, B. Hedgehogs and mustelid species: Major carriers of pathogenic Leptospira, a survey in 28 animal species in France (20122015). *PLoS ONE* **2016**, *11*, e0162549. [CrossRef] [PubMed]
28. Ma, X.J.; Gong, X.Q.; Xiao, X.; Liu, J.W.; Han, H.J.; Qin, X.R.; Lei, S.C.; Gu, X.L.; Yu, H.; Yu, X.J. Detection of *Leptospira interrogans* in hedgehogs from Central China. *Vector Borne Zoonotic Dis.* **2020**, *20*, 427–431. [CrossRef]
29. Brockie, R.E.; Till, D.G. Leptospira ballum isolated from hedgehogs. *N. Z. Vet. J.* **1977**, *25*, 28–30. [CrossRef]
30. Bharti, A.R.; Nally, J.E.; Ricaldi, J.N.; Matthias, M.A.; Diaz, M.M.; Lovett, M.A.; Levett, P.N.; Gilman, H.R.; Willing, M.R.; Gotuzzo, E.; et al. Leptospirosis: A zoonotic disease of global importance. *Lancet Infect. Dis.* **2003**, *3*, 757–771. [CrossRef]
31. Majerová, K.; Hönig, V.; Houda, M.; Papežík, P.; Fonville, M.; Sprong, H.; Rudenko, N.; Golovchenko, M.; Černá Bolfíko-vá, B.; Hulva, P.; et al. Hedgehogs, Squirrels, and Blackbirds as Sentinel Hosts for Active Surveillance of Borrelia miyamotoi and Borrelia burgdorferi Complex in Urban and Rural Environments. *Microorganisms* **2020**, *8*, 1908. [CrossRef]
32. Gong, X.Q.; Xiao, X.; Liu, J.W.; Han, H.J.; Qin, X.R.; Lei, S.C.; Yu, X.-J. Occurrence and Genotyping of Coxiella burnetii in Hedgehogs in China. *Vector Borne Zoonotic Dis.* **2020**, *20*, 580–585. [CrossRef]
33. Bengtsson, B.; Persson, L.; Ekström, K.; Unnerstad, H.E.; Uhlhorn, H.; Börjesson, S. High occurrence of mecC-MRSA in wild hedgehogs (*Erinaceus europaeus*) in Sweden. *Vet. Microbiol.* **2017**, *207*, 103–107. [CrossRef]
34. Rodenbaugh, C.; Ramachandran, A.; Brandão, J. Lancefield Group A Streptococcus-Associated Dermatitis in an African Pygmy Hedgehog (*Atelerix albiventris*). *J. Exot. Pet. Med.* **2020**, *33*, 27–30. [CrossRef]
35. Monecke, S.; Gavier-Widen, D.; Mattsson, R.; Rangstrup-Christensen, L.; Lazaris, A.; Coleman, D.C.; Shore, A.C.; Ehricht, R. Detection of mecC-positive Staphylococcus aureus (CC130-MRSA-XI) in diseased European hedgehogs (*Erinaceus europaeus*) in Sweden. *PLoS ONE* **2013**, *8*, e66166. [CrossRef]
36. Rasmussen, S.L.; Larsen, J.; van Wijk, R.E.; Jones, O.R.; Berg, T.B.; Angen, Ø.; Larsen, A.R. European hedgehogs (*Erinaceus europaeus*) as a natural reservoir of methicillin-resistant *Staphylococcus aureus* carrying mecC in Denmark. *PLoS ONE* **2019**, *14*, e0222031. [CrossRef] [PubMed]
37. Lugton, I.W.; Johnstone, A.C.; Morris, R.S. Mycobacterium bovis infection in New Zealand hedgehogs (*Erinaceus europaeus*). *N. Z. Vet. J.* **1995**, *43*, 342–345. [CrossRef] [PubMed]
38. Tappe, J.P.; Weitzman, I.; Liu, S.; Dolensek, E.P.; Karp, D. Systemic Mycobacterium marinum infection in a European hedgehog. *J. Am. Vet. Med. Assoc.* **1983**, *183*, 1280–1281. [CrossRef] [PubMed]
39. Nakamura, S.I.; Yasuda, M.; Ozaki, K.; Tsukahara, T. Eosinophilic Leukaemia and Systemic Mycobacterium marinum In-fection in an African Pygmy Hedgehog (*Atelerix albiventris*). *J. Comp. Pathol.* **2020**, *181*, 33–37. [CrossRef]

40. Jahfari, S.; Hofhuis, A.; Fonville, M.; van der Giessen, J.; van Pelt, W.; Sprong, H. Molecular detection of tick-borne path-ogens in humans with tick bites and erythema migrans, in the Netherlands. *PLoS Negl. Trop. Dis.* **2016**, *10*, e0005042. [CrossRef]
41. Skuballa, J.; Petney, T.; Pfäffle, M.; Oehme, R.; Hartelt, K.; Fingerle, V.; Kimmig, P.; Taraschewski, H. Occurrence of different Borrelia burgdorferi sensu lato genospecies including *B. afzelii*, *B. bavariensis*, and *B. spielmanii* in hedgehogs (*Erinaceus* spp.) in Europe. *Tick Borne Dis.* **2012**, *3*, 8–13. [CrossRef]
42. Burgdorfer, W.; Barbour, A.G.; Hayes, S.F.; Benach, J.L.; Grunwaldt, E.; Davis, J.P. Lyme disease- a tick-borne spirochetosis? *Science* **1982**, *216*, 1317–1319. [CrossRef]
43. Philpot, C.M.; Bowen, R.G. Hazards from hedgehogs: Two case reports with a survey of the epidemiology of hedgehog ringworm. *Clin. Exp. Dermatol.* **1992**, *17*, 156–158. [CrossRef] [PubMed]
44. Perrier, P.; Monod, M. Tinea manuum caused by Trichophyton erinacei: First report in Switzerland. *Int. J. Dermatol.* **2015**, *54*, 959–960. [CrossRef]
45. Choi, E.; Huang, J.; Chew, K.L.; Jaffar, H.; Tan, C. Pustular tinea manuum from *Trichophyton erinacei* infection. *JAAD Case Rep.* **2018**, *4*, 518. [CrossRef] [PubMed]
46. Kottferová, L.; Molnár, L.; Major, P.; Sesztáková, E.; Kuzyšinová, K.; Vrabec, V.; Kottferová, J. Hedgehog dermatophytosis: Under-standing Trichophyton erinacei infection in pet hedgehogs and its implications for human health. *J. Fungi* **2023**, *9*, 1132. [CrossRef] [PubMed]
47. Lumbán-Ramírez, P.; Lumbán-Ramírez, F.; de Oca-Loyola, M.L.M.; Jaramillo-Manzur, S.C.; Bonifaz, A. Tineas due to Trichophyton erinacei: An emerging disease? *Curr. Fungal Infect. Rep.* **2024**, *18*, 102–111. [CrossRef]
48. English, M.P. Ringworm in wild mammals: Further investigations. *J. Zool.* **1969**, *159*, 515–522. [CrossRef]
49. Abarca, M.L.; Castellá, G.; Martorell, J.; Cabañes, F.J. Trichophyton erinacei in pet hedgehogs in Spain: Occurrence and revision of its taxonomic status. *Med. Mycol.* **2017**, *55*, 164–172. [CrossRef]
50. Smith, J.M.B.; Marples, M.J. Trichophyton mentagrophytes var. erinacei. *Sabouraudia* **1964**, *3*, 1–10. [CrossRef]
51. Yu, X.J.; Liang, M.F.; Zhang, S.Y.; Liu, Y.; Li, J.D.; Sun, Y.L.; Zhang, L.; Zhang, Q.F.; Popov, V.L.; Li, C.; et al. Fever with thrombocytopenia associated with a novel bunyavirus in China. *N. Engl. J. Med.* **2011**, *364*, 1523–1532. [CrossRef]
52. Takahashi, T.; Maeda, K.; Suzuki, T.; Ishido, A.; Shigeoka, T.; Tominaga, T.; Kamei, T.; Honda, M.; Ninomiya, D.; Sakai, T.; et al. The first identification and retrospective study of severe fever with thrombocytopenia syndrome in Japan. *J. Infect. Dis.* **2014**, *209*, 816–827. [CrossRef]
53. Lin, T.L.; Ou, S.C.; Maeda, K.; Shimoda, H.; Chan, J.P.W.; Tu, W.C.; Hsu, W.L.; Chou, C.C. The first discovery of severe fever with thrombocytopenia syndrome virus in Taiwan. *Emerg. Microbes Infect.* **2020**, *9*, 148–151. [CrossRef] [PubMed]
54. Sun, Y.; Liu, M.M.; Luo, L.M.; Zhao, L.; Wen, H.L.; Zhang, Z.T.; Liu, J.W.; Xue, Z.F.; Ma, D.Q.; Ding, S.J. Seropreva-lence of severe fever with Thrombocytopenia syndrome virus in hedgehog from China. *Vector Borne Zoonotic Dis.* **2017**, *17*, 347–350. [CrossRef] [PubMed]
55. Mansfield, K.L.; Johnson, N.; Phipps, L.P.; Stephenson, J.R.; Fooks, A.R.; Solomon, T. Tick-borne encephalitis virus—A review of an emerging zoonosis. *J. Gen. Virol.* **2009**, *90*, 1781–1794. [CrossRef]
56. Schönbächler, K.; Hatt, J.M.; Silaghi, C.; Merz, N.; Fraefel, C.; Bachofen, C. Frühsommer-Meningoenzephalitis-Virus Na-chweis beim Europäischen Igel (*Erinaceus europaeus*). *Schweiz. Arch. Tierheilkd.* **2019**, *161*, 23–31. [CrossRef] [PubMed]
57. Delogu, M.; Cotti, C.; Lelli, D.; Sozzi, E.; Trogu, T.; Lavazza, A.; Garuti, G.; Castrucci, M.R.; Vaccari, G.; De Marco, M.A.; et al. Ecovirological preliminary study of potentially emerging pathogens in hedgehogs (*Erinaceus europaeus*) recovered at a wildlife treatment and rehabilitation center in Northern Italy. *Animals* **2020**, *10*, 407. [CrossRef]
58. Vanmechelen, B.; Vergote, V.; Merino, M.; Verbeken, E.; Maes, P. Common occurrence of Belerina virus, a novel para-myxovirus found in Belgian hedgehogs. *Sci. Rep.* **2020**, *10*, 19341. [CrossRef] [PubMed]
59. Ekici, M.; Keskin, A.; Bursali, A.; Tekin, S. Investigation of Crimean Congo Hemorrhagic Fever Virus in Ticks (Acari: Ix-odidae) Infesting on Hedgehogs in Turkey. *J. New Res. Sci.* **2013**, *2*, 31–38.
60. Farago, Z. Rabid hedgehog in inner-city area of Budapest. *Orvosi Hetil.* **1997**, *138*, 2231–2232.
61. Franklinos, L.H.; Efstratiou, A.; Macgregor, S.K.; John, S.K.; Hopkins, T.; Cunningham, A.A.; Lawson, B. Streptococcus pyogenes infection in a free-living European hedgehog (*Erinaceus europaeus*). *Ecohealth* **2015**, *12*, 689–692. [CrossRef]
62. Allison, N.; Chang, T.; Steele, K.; Hilliard, J.K. Fatal herpes simplex infection in a pygmy African hedgehog (*Atalerix albiventris*). *J. Comp. Pathol.* **2002**, *126*, 76–78. [CrossRef]
63. Hydeskov, H.B.; Dastjerdi, A.; Hopkins, K.P.; Ryser-Degiorgis, M.-P.; Widén, F.; Cunningham, A.A.; Lawson, B. Detection and characterisation of multiple herpesviruses in free-living Western European hedgehogs (*Erinaceus europaeus*). *Sci. Rep.* **2018**, *8*, 13942. [CrossRef] [PubMed]
64. Pomorska-Mól, M.; Ruszkowski, J.J.; Gogulski, M.; Domanska-Blicharz, K. First detection of Hedgehog coronavirus 1 in Poland. *Sci. Rep.* **2022**, *12*, 2386. [CrossRef]
65. Lau, S.K.P.; Luk, H.K.H.; Wong, A.C.P.; Fan, R.Y.Y.; Lam, C.S.F.; Li, K.S.M.; Ahmed, S.S.; Chow, F.W.N.; Cai, J.-P.; Zhu, X.; et al. Identification of a Novel Betacoronavirus (Merbecovirus) in Amur Hedgehogs from China. *Viruses* **2019**, *11*, 980. [CrossRef]

66. Daszak, P.; Cunningham, A.A.; Hyatt, A.D. Anthropogenic environmental change and the emergence of infectious diseases in wildlife. *Acta Trop.* **2001**, *78*, 103–116. [CrossRef] [PubMed]
67. Messenger, A.M.; Barnes, A.N.; Gray, G.C. Reverse zoonotic disease transmission (zooanthroponosis): A systematic review of seldom-documented human biological threats to animals. *PLoS ONE* **2014**, *9*, e89055. [CrossRef]
68. App, M.; Strohbach, M.W.; Schneider, A.-K.; Schröder, B. Making the case for gardens: Estimating the contribution of urban gardens to habitat provision and connectivity based on hedgehogs (*Erinaceus europaeus*). *Landsc. Urban Plan.* **2022**, *220*, 104347. [CrossRef]
69. Lukešová, G.; Voslarova, E.; Vecerek, V.; Vucinic, M. Trends in intake and outcomes for European hedgehog (*Erinaceus europaeus*) in the Czech rescue centers. *PLoS ONE* **2021**, *16*, e0248422. [CrossRef]
70. Greigert, V.; Brunet, J.; Ouarti, B.; Laroche, M.; Pfaff, A.W.; Henon, N.; Lemoine, J.-P.; Mathieu, B.; Parola, P.; Candolfi, E.; et al. The Trick of the Hedgehog: Case Report and Short Review About *Archaeopsylla erinacei* (Siphonaptera: Pulicidae) in Human Health. *J. Med. Entomol.* **2020**, *57*, 318–323. [CrossRef]
71. Földvári, G.; Rigó, K.; Jablonszky, M.; Biró, N.; Majoros, G.; Molnár, V.; Tóth, M. Ticks and the city: Ectoparasites of the Northern white-breasted hedgehog (*Erinaceus roumanicus*) in an urban park. *Ticks Tick Borne Dis.* **2011**, *2*, 231–234. [CrossRef]