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# Wild Mammal Translocations: A Public Health Concern

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## Abstract

With regard to wildlife translocations and the assessment of potential risk of disease transmission, several advances have been made in conservative projects. However, other factors like the large number of species received at screening centers from different locations, rescued after being hit by vehicles, taken by the public or confiscated from illegal trade by the authorities, have increased the risk of spreading, emergence or reemergence of zoonosis. Besides the notorious importance of the procedure improvement for managing wildlife, the access to as much as possible information about the occurrence of potential infections on each particular species can be a tool of great value for mitigating the disease risk. In the present paper, it was showed the evolution of processes for wildlife translocations mostly related to mammals, we also discussed some aspects related to sylvatic animals as reservoir host of zoonosis and finally were presented several tables recording numerous mammals hosts and their respective parasitic protozoa.

## Keywords

Mammals, Wildlife Translocations, Zoonosis, Parasitic Protozoa

## 1. Introduction

Zoonosis can be defined as diseases or infections that are naturally transmitted between animals and humans. The diverse kinds of potential infectious organisms encompassing viruses, fungi, bacteria as well as parasites they can produce zoonotic infections and seventy-five per cent of the emerging human diseases were determined as zoonosis [1].

Consequently, it should be considered as a significant warning for global pub-

lic health.

Among the causal factors for the emerging or re-emerging of zoonosis is the increase in human-assisted movement of animals and anthropogenic changes that alter the distribution of wild hosts and vectors promoting the spreading of infectious agents.

The knowledge about the jeopardy of microorganism transmission involving the wildlife relocation has been progressing substantially since the last century.

Unfortunately, in spite of the great advancement in the procedures to avoid that kind of microorganisms, transmission, the achievement of effective measures in many countries is still incipient and the lack of information about those infectious agents and their wild hosts still represents a gap.

In the present paper, we presented firstly a review from bibliography related to disease risk and wildlife translocations, principally related to wild mammals.

After, it was discussed some results from the literature and finally, based on the molecular classification of placentals proposed by Tarver *et al.* [2], a table was presented showing infection records of several wild host mammal species and their respective parasitic protozoa, most of them with medico-veterinary importance.

One of the first reports about the risk of microorganism transmission involving the wildlife relocation was presented by Jirovec [3].

He showed that an avirulent microorganism that causes imperceptible infection in wild animal hosts could sometimes become virulent after the passage through a new host in a new environment.

The author mentioned one case of rabbits (*Lepus cuniculus*), translocated from England to South Africa. Some of the animals in England (5.7%) were infected by an avirulent strain of *Toxoplasma*. After arriving in South Africa, the parasite infected local rats (*Rattus natalensis*) and in these new hosts, a virulent form of the parasite selected.

Later, Jacobson *et al.* [4], from the investigation on the epizootiology of an outbreak of cerebrospinal nematodiasis in cottontail rabbits and woodchucks in USA, triggered by the introduction of racoons.

They concluded that because of the potential consequences of this disease in small mammal populations, the raccoons should be examined, prior to relocation.

Moreover, the authors underlined the public health aspect, of potential parasite translocation through those animals.

May and Lyles [5] analyzed a reintroduction program of captive tamarins in the native habitat in Poço das Antas Biological Reserve, Brazil, according to the authors after about two years, out of the 26 animals only five were alive with diseases as the leading cause of death.

Nettles [6] introduced the term "biological package" referring that a translocated animal is not a representative of a single species, but it is considerably a set of viruses, bacteria, protozoa, helminths and arthropods.

Rosatte and Maclnnes [7] studied one group of raccoons from Toronto (CA),

translocated to either rural areas or a town.

They argued as not recommending the relocation of those animals, because their high exploratory movements and a potential risk for disease transmission.

Griffith *et al.* [8] presented a review of terrestrial vertebrate animals from 1973 to 1986, in Australia, Canada, New Zealand and the USA, analyzing the geographical distribution and relative frequency of translocations methods that had disease transmission implications.

They related that translocations probably exceed 700 per year and more than 50% of assessed agencies have translocated some species each year.

On average, 26% were captive-reared animals, 29 were released to areas on the periphery or outside of the species ranges.

Only 32% provided post-release follow up and in 24%, there were no checkups carried out by professionals related to the occurrence of parasite infections, diseases or any kind of wound.

The authors stated that a suitable valuation on the effect of disease on translocation success would require multivariate analyses.

Viggers *et al.* [9] discussed the importance of disease in reintroduction programs. They pointed out that disease could play a significant role in the reduction or extinction of small isolated animal populations.

Furthermore, a remaining wild population could be strongly reduced by a disease co-introduced with relocated animals. Conversely, endemic diseases in wild animal populations could be deadly for those immunologically naive reintroduced individuals.

Munson and Cook [10] indicated the necessity of conservation programs for captive breeding and reintroducing of threatened and endangered species, for assessing the risk of introducing infectious disease into or acquiring diseases from the reintroduction environment.

The authors pointed that risk evaluation was seriously disadvantaged by insufficient knowledge about the disease. Thus, it was suggested that integrating information from diverse sources would be greatly simplified by establishing standards for data collection. Guideline instructions for monitoring and investigating the infectious diseases would provide essential information for a disease database.

It was also proposed, the creation of a method for categorizing infectious diseases by degree of threat to a species or environment, for the limited resources in support of disease investigations being appropriately allocated. Furthermore, these methods would meaningfully increase the understanding of disease epidemiology in nondomestic species.

Woodford and Rossiter [11] described some subjects of the disease risks attending wildlife translocation projects they also suggested the development of systematic procedures to reduce these risks both at the source of the founder animals and at the proposed release site.

The same authors in 1994, working in the above-mentioned projects, they

presented one of the first attempts to establish guidelines for assessing disease risk in wildlife translocations.

The following topics were proposed:

1) Types of disease risk.

2) Diseases introduced by translocated animals.

3) Diseases encountered by translocated animals at the release site.

4) Minimizing the risks.

5) Interpretation of survey and screening results.

6) Vaccination of founders.

7) Post-release health monitoring.

8) Disease transmission hazards with cryopreserved germplasm.

In our view, the cryopreservation of microorganism samples corresponds to a very important measure, because isolate and preserve biological samples from sylvatic animals is fundamental for studies in diverse approaches like biology, pathology, genetics, proteomics and many others.

These samples could be fundamental permitting identify, characterize and studding potential pathogenic organisms, for the animals but also with potential risk to public health.

Mihok *et al.* [12], recorded some health consequences related to the translocations of endangered species in Africa, specifically associated with cases of *Trypanosoma* infections in rhinoceros.

The survey included both, black (*Diceros bicornis*) and white (*Ceratotherium simum*) rhinoceros that had lived before in areas free from *T. brucei* and were translocated to low lands characteristically associated to the occurrence of tsetse flies, the insect vectors of different species of trypanosomes.

In both mammal species there were deaths because the parasite infections and although previous examinations from blood smears revealed low infections incidence, posterior serological tests demonstrated that most animals presented subpatent infections.

Particularly concerning to the white rhinoceros the authors concluded that this species would be a good sylvatic host to *T. brucei*, likewise it was highlighted the potential serious consequences for management plans involving this species into or out the areas with human sleeping sickness and the possibility of spreading the disease to new areas.

Karesh and Cook [13] pondered about the importance of the incorporation of veterinary medicine on a multidisciplinary approach for assessment the elaboration and execution of conservation projects.

Besides their expertise for immobilizing animals, they could contribute on the follow up the health of sylvatic animals, as well as in the training of others for working and supervising wildlife.

It was stated that, wildlife health care should include six steps.

The first step proposed, was identifying critical health-related factors that could affect wildlife populations, recognizing the role of diseases in the dynamics

of those populations.

According the authors, the host-parasite relationship should be considered as very complex condition, including multivariate factors like bacterial, viral and fungal infections besides nutritional, metabolic, genetic and toxicological problems.

In function of that, wide-ranging health surveys comprising all those factors should be implemented for most threatened and endangered species and those studies should include even probably involved sympatric species.

Like other authors have already proposed, that survey should be carried out for a multidisciplinary team for assembling overall health profiles related to wildlife populations.

The second step proposed by Karesh and Cook [13], was the monitoring the health status of wildlife populations over time, because those information could be employed on future conservation strategies.

Moreover, the following premises were proposed in respect to programs of disease-monitoring:

1) Function as signs of environmental degradation showing potential threats and alterations in the health of populations, because they normally precede the variations in population size or structure.

2) Provide qualitative and quantitative data for population viability analysis (PVA) programs. Taking into account that the inclusion of the health was supposed to be fundamental for a comprehensive assessment of population viability.

3) Support on the definition of the aptness of wildlife populations for translocation, restocking, reintroduction or restoration ecology projects. By the evaluation of area or the animals to be introduced, in function of the diseases they could be harboring and for their immunity to agents to which they could be exposed during the process.

Both, the animals as well as the selected areas for receiving them should be evaluated for the occurrence of diseases or the risk of new pathogens introduction.

The other promises in summary comprised of: a) Crisis intervention, b) Animal handling and welfare and c) New technologies. Concerning respectively to, diagnosis during a health crisis or wildlife die off; handling of wildlife, specifying equipment; and practices for reducing possible animal wounds.

In conclusion, the authors indicated the veterinary sciences could supply conservation programs in respect to the several points above mentioned and their function in conservation efforts would need to increase for encountering the requirements of governmental and nongovernmental programs around the world.

Cunninghan [14] discussed the possible adverse effects on the evolution of ecosystems because disease transmission resulting from wildlife translocations.

Revising the literature, he referred several authors to highlight that certain diseases can cause on the fauna severe negative effects such as, increased of susceptibility to predation, lower reproductive capacity and death.

It was also recorded the great effect of diseases on individual fitness, considered an important factor in the maintenance of biodiversity. Those effects could also present more complex situation, like diseases that cause a decline on the population of a determined species that is a staple prey of some predator, consequently it may trigger a selective pressure causing reductions on the predator number.

On the other wise, the author remembered that diseases are important to the maintenance of biodiversity, because it influences the species complement within established ecosystems.

Indeed, Cunninghan [14] stressed that although the mechanisms involving parasite infections on community structures within ecosystems were poorly understood, it should not be overlooked when wildlife translocation programs are developed.

Another important question raised by Cunninghan [14] was about keeping time of sylvatic animals in captivity.

He suggested that animals in captivity would be at risk of infection with parasites that are foreign respectively to, a particular species, the area of origin, the area where will be introduced or a combination of the three. Besides, the risks of outbreaks of disease increase while an animal has been kept in captivity and further away from its natural habitat.

For reducing the risks, the author suggested the adopting of very important measures, for caught animals as well as whose progeny that would be further reintroduced:

1) The animals must be maintained in captivity as near as possible to the site of capture.

2) The animals should be held captive for as short a time as possible.

3) Avoid direct or indirect contacts between the animals from different sources or species.

4) The animals should be Kept and managed under hygienic conditions to minimize the risk of parasites being passed from the keepers to them.

5) Control of foodstuff for avoiding transmission of parasites to the animals.

The author reasoned it would seem desirable for animals in captivity to be kept parasite-free, but the parasites they could harbor were those they would be exposed to in their natural territory.

The maintenance of such parasite burden and consequently the continuation of genetic and other adaptations to these parasites could be an advantage for ensuring the survival of animals once they are reintroduced to the wild.

It also could allow the conserving the parasites biodiversity, in spite of the necessity for controlling the infections to avoid probable deleterious effects produced by captivity.

Completing, Cunninghan [14] presented five more points: 1) Specimens with no registered disease, does not mean that they are not susceptible to the disease. 2) Animals of any age can carry, or be susceptible to pathogenic organisms. 3)

Clinically healthy animals should not be considered as free of parasites; thus, equal attention and prerequisites should be requested to all animals in each stages of the life; but the methods applied for parasites detection would depend on the species, stage of the life cycle, as well as the methodology of the reintroduction program. 4) Translocation of animals to areas lacking of related species would reduce the risk of interspecific transmission of the disease. 5) If evaluation and reduction of risk would be not possible, the program should only be continued in cases that the conservation risk for not having been made was greater in order to avoid the introduction of parasites into new areas.

Likewise, it is accepted that the introduction of other exotic species, usually into new habitats, should be avoided.

Among the conclusions, the author indicated that previously of making a wildlife translocation the disease risks should be correctly evaluated and preventive measures should be taken to reduce the risks.

In 1998 The International Union for Conservation of Nature and Natural Resources (IUCN) [15], published one of their first comprehensive guidelines that were considered as necessary to make available a more comprehensive coverage of the several factors related to re-introduction.

The background for that guidelines, was relating to policies directed to biodiversity conservation and sustainable management of natural resources.

It was highlighted the procedures should represent useful tools for re-introduction programs and do not a rigid code of conduct.

Among diverse themes mentioned, the restoring of ecosystems regarding to re-introduction of species was discussed and considered a very common practice around the world. Thus, the IUCN Species Survival Commission's Re-introduction Specialist Group developed those guidelines.

They were based on reviews and case-histories and were thought that could institute more thoroughness into the elaboration of concepts, design, feasibility and in implementation of re-introductions.

The definition of the terms "re-introduction", "translocation", "reinforcement/supplementation" and "conservation/benign introductions" were presented.

The aims and objectives were correspondingly related to the long-term survival or re-establishing of important species, for preserving and/or restoration of natural biodiversity, producing long-term economic benefits and stimulating conservation consciousness.

It was remembered the need of a multidisciplinary approach to support re-introduction projects including governmental natural resource management agencies, non-governmental organizations, funding bodies; universities; veterinary institutions; zoos, etc.

Some statements related to re-introduction projects, were presented including: 1) pre-project activities, 2) planning, preparation and release stages and 3) post-release activities. In the two firsts, was related the concerning about the ac-

quisition and/or spreading of diseases.

Composing Pre-project activities, in the feasibility study and background research, it was suggested the application of detailed surveys on the status and biology of wild animal populations. Disease was included among several factors to identify the critical needs of the species like, habitat preferences, intraspecific variation, home range size, shelter, feeding behavior, predators etc.

In the planning, preparation and release stages, the choice of release site and type, it should be within the historic range of the species and for a re-introduction, no remnant population could exist to prevent disease spreading, social disruption and introduction of alien genes.

On the evaluation of re-introduction site, several actions were suggested for the detection, diminution or removal, of causes of population decline such as diseases, over-hunting, over-collection, pollution, poisoning, competition with or predation by introduced species and habitat loss.

The availability of suitable release stock for minimizing infectious disease risk should be implemented, seeing that grave diseases could occur during shipment.

When considered wild-caught release stock, attention to ensuring that animals were non-infected with contagious pathogens and parasites before shipment and not be exposed to vectors of disease agents which may be present at the release site to which they would have no acquired immunity.

The immunization, against diseases of wild or domestic animals of the release site, should be done during "Preparation Stage" at enough time for the immunity development.

Woodford [16] was one the first authors that compiled data concerning quarantine and health screening procedures for wildlife prior to translocation and release into the wild. It was also suggested treatment and immunization protocols for mammals, birds, reptiles, amphibians and fish.

The author reinforces the idea that translocation from one wild population, or introduction of captive-borne animals in the wild as well as the return of convalesced animals after some time in captivity, should be taken into account as a risk of disease transfer.

It was reminded the concept proposed by Nettles [6] of biological package besides aiming the possibility of certain organisms become pathogenic under host stressful situations, affecting as the released specimen as well as the other animals but principally putting human population under risk.

Woodford [16] presented very useful information related to the measures for caught animals as well as whose progeny that would be further reintroduced, including several animal groups from fish to Primates as follows: Artiodactyla, Perissodactlya, Primates, Carnivora, marine Mammalia, Rodentia, Lagomorpha, Marsupialia, Monotremata, Chiroptera, Birds, Reptilia, Amphibia and Piscidae.

Corn and Nettles [17] presented health protocol for translocation of free-ranging elk (*Cervus elaphus*).

The protocol was based on five components:

1) Evaluation of the health status of source populations.

2) Quarantines.

3) Physical examination.

4) Restrictions on translocation.

5) Prophylactic treatment.

They suggested that wildlife managers should assess the positive and negative elements of translocation before initiate a restoration plan.

A selected set of epidemiologic factors related to infectious agents and ectoparasites were evaluated through a qualitative analysis for determining its potential to be introduced and to become established.

Infectious agents and ectoparasites of unknown risks were classified as: *Anaplasma marginale*, *Anaplasma ovis*, *Mycobacterium paratuberculosis*, *Pasteurella multocida serotype* 3, *Elaphostrongylus cervi*, *Dicrocoelium dendriticum*, *Fascioloides magna*, *Echinococcus granulosus*, *Dermacentor albipictus*, *and Otobius megnini.*

Of high risk were: Chronic wasting disease, *Brucella abortus*, *Mycobacterium bovis*, *Parelaphostrongylus tenuis*, *Elaeophora schneideri*, *Babesia sp. and Dermacentor andersoni*, *Ixodes pacificus* and *Psoroptes sp.*

Lafferty and Gerber [18] presented a very interesting approach concerning the intersection of epidemiology and conservation theory.

They stated that infectious disease would be a concern for diverse features of conservation biology such as, the determining threats species, estimating population viability, designing reserves, captive breeding, and recovery programs.

The authors showed some correlation between infectious diseases and population density, susceptibility and pathogen exposure.

Actually, infectious-disease transmission usually increases when the density of the host species augment.

On the other hand, species with a decreasing number of individuals would be more susceptible for host-specific infectious diseases. Nonetheless, conditions like habitat fragmentation or captivity that cause in increased contact facilitate disease spread among individuals even in a declining species.

It was also supposed, that there was no a linear correlation between the outcome of infectious diseases and pathology in individual hosts. So infectious agents that kill fast their hosts, present a tendency to become locally extinct, consequently organisms with intermediate pathogenicity would be responsible for the highest negative effects on a host population density.

Several records of infectious diseases of hosts considered as of conservation concern were tabulated for providing evidence that infectious agents could reduce population density or inhibit the species recovering.

**Table 1** was based on the results of Lafferty and Gerber [18] where were included only the results related to mammals, recording the host, infectious agent, source of the infection and consequences of the disease on the population.

**Table 1.** Infectious diseases that have caused negative effects on mammal host species of conservation concern.

| Host | Disease agent | Transmission | Origin | Consequences |
|---|---|---|---|---|
| Koala (*Phascolarctos cinereus*) | Chlamydia | STD | Native | Birth rate declined |
| Red squirrel (*Sciurus vulgaris*) | Parapoxvirus | Direct | Introduced grey squirrel | 90% population reduction |
| wolf (*Canis lupus*) | Rabies | Direct | Arctic fox (*Vulpes lagopus*) | 60% population reduction |
| African ungulates | Rinderpest | Direct | Domestic cattle | 80% population reduction |
| Bighorn sheep (*Ovis canadensis*) | Scabies *Psoroptes ovis*<br>Cholera *V. colarae* | Direct | Arthropod<br>Domestic sheep | 80% population reduction<br>Local extinction |
| Sea otter (*Enhydralutrisnereis*) | Acanthocephalan | Native birds | Trophic | Increased mortality |
| Allegheny wood rat (*Neotoma magister*) | Larval migrans | Subsidized raccoons | Trophic | Local extinction |
| African lion (*Panthera leo*) | Canine distemper | Domestic dogs | Direct | 33% reduction |
| African wild dog (*Lycaon pictus*) | .Canine distemper<br>Rabies | Domestic dogs/jackal | Direct | Local extinction |
| Black-footed ferret (*Mustela nigripes*) | Canine distemper | Live vaccine | Direct | 90% reduction |
| Wolf (*Canis lupus*) | Parvovirus | Domestic dogs | Direct | Reduced recovery |
| Ethiopian wolf (*Canis simensis*) | Rabies | Domestic dogs | Direct | 50% density |
| Koala (*P.cinereus*) | *Chlamydia ssp* | STD | Native | Birth rate declined |
| Red squirrel (*S. vulgaris*) | Parapoxvirus | Direct | Introduced grey squirrel | 90% population reduction |
| wolf (*C. lupus*) | Rabies | Direct | Arctic fox (*V. lagopus*) | 60% population reduction |
| African ungulates | Rinderpest | Direct | Domestic cattle | 80% population reduction |
| Bighorn sheep (*O. canadensis*) | Scabies *Psoroptes ovis* | Direct | Arthropod | 80% population reduction |
| Bighorn sheep (*O.canadensis*) | Cholera | Domestic sheep | Direct | Local extinction |
| Sea otter (*E. nereis*) | Acanthocephalan | Native birds | Trophic | Increased mortality |
| Allegheny wood rat (*N. magister*) | Larva migrans<br>*B. procyonis* | Subsidized raccoons | Trophic | Local extinction |
| African lion (*P. leo*) | Canine distemper<br>Morbillivirus | Domestic dogs | Direct | 33% reduction |
| African wild dog (*L. pictus*) | Canine distemper<br>Morbillivirus | Domestic dogs/jackal | Direct | Local extinction |
| Black-footed ferret (*M. nigripes*) | Canine distemper<br>Morbillivirus | Live vaccine | Direct | 90% reduction |
| Wolf (*C. lupus*) | Parvovirus | Domestic dogs | Direct | Reduced recovery |
| Ethiopian wolf (*C. simensis*) | Rabies | Domestic dogs | Direct | 50% density |
| African wild dog (*L.pictus*) | Rabies | Domestic dogs/jackal | Direct | Local extinction |

Based on the results of Lafferty K.D. and Gerber L.R. [18]. STD: sexually transmitted diseases.

In Conclusion, Lafferty and Gerber [18] emphasized the importance of making an interaction between conservation biology and epidemiology. It was suggested that probable important infectious diseases for threatened species could be those with wide-ranging host species. Therefore disease investigation besides crowding decrease, avoiding inbreeding and selection for susceptibility, they

could support conservation biologists on the understanding of disease risks.

Gaydos and Gilardi [19], addressed disease risks when recovering species at risk.

They maintained that diseases have great influences on free-ranging wildlife populations, and could be especially important in the case of recovering species at risk.

In the need of translocation or captive breeding, which could enhance the risk of disease impacts, it was suggested a process comprised of steps for deal with species at risk, summarized below:

1) Disease should be considered as a reason that could affect the success of recovery efforts of a species.

2) Potential important diseases should be assessed.

3) The third step presented by the authors must be considered of great importance because highlighted the awareness regarding the risk of introducing diseases when translocating or propagating species at risk in captivity. Besides, it should be cogitated the probable existence of new diseases not yet recorded for the species in question.

4) Treatment or vaccinations of individuals besides manipulating the pathogen or toxin, the population, the environment, and/or human activities, should be considered accessible strategies for disease management.

5) Checking disease management strategies is important to assess effectiveness.

In conclusion, Gaydos and Gilardi [19] agreed that diseases are potential risk to the continuing viability of recovery of threatened or endangered species. Thus, it should be the first action, the prevention of disease-related problems.

They highlighted the necessity to continuous appraisal of disease risks and impacts throughout the recovery process. Considering disease is one the main ecological force, the detection and the diminishing of risks could be a significant component for wildlife recovering.

Gerber *et al.* [20] argued about the exposing pathogens to a population and the analysis of extinction risk, besides questioning if disease is simply one more example of density dependence.

They pointed out as an important measure, the development of population viability analyses (PVA) as a legal requirement in the United States and several other countries, being mandatory the applying of PVA in any plan elaborated for threatened and endangered species.

Nevertheless, regardless of the significance of the pathogens effects on the native populations, according to the authors insufficient attention was given to host–pathogen dynamics concerning PVA.

They reviewed the relevance on the host-pathogen interaction on the extinction risk and estimated through PVA the potential impact of infectious diseases on host population.

Furthermore, a density-dependent host-parasite stochastic model was created to examine the consequences of disease on the preservation of endangered pop-

ulations.

It was also showed that the model developed converged on a Ricker model of density dependence under a set of constraining suppositions, comprised a high probability that epidemics would arrive and occur.

Note: The Ricker model, constitutes in a classic discrete population mathematical model which presents an expected number $N_{t+1}$ (or density) of individuals in generation $t + 1$ as a function of the number of individuals in the previous generation.

Through that approach, they observed:

1) Distinctions between time series produced by disease and Ricker processes.

2) Probabilities of quasi-extinction for populations exposed to disease or self-limitation.

3) A tendency in quasi-extinction chances estimated by density-independent PVAs when populations undergone any type of density dependence.

Concerning the relationships among disease, PVA and dealing with endangered species, the authors proposed two hypothetical situations.

1) Disease more strongly increased variability in host abundance and, thus, the probability of quasi-extinction than did self-limitation.

2) Estimates of quasi extinction were more often overly optimistic for populations experiencing disease than for those subject to self-limitation.

According the authors population density is an important factor for both PVA and the host-pathogen theory.

A fundamental principle of epidemiology lies on the concept that the dispersion of an infectious disease within a population is a function of the density of the susceptible as well as the infectious hosts.

Consequently, in the cases where infectious agents would be tolerable by the host species, the pathogen effect on declining population would probably drop with the host population decreasing.

In addition, the authors mentioned that a pathogen would be able to spread when it was competent to be transmitted to another host before the current host dies or eliminates the infection.

Thus, when parasites influences the host reproduction or mortality, or the host is able to control the infection, the parasite population could eventually be reduced because of the decrease on the number of susceptible hosts, eventually stopping infection incidence.

Likewise, epidemiological models generally show the existence of a host density limit or native population size, restraining the parasite ability to infect new hosts. It would imply that some concerned species should be less exposed to host-specific disease.

In conclusion, the authors suggested that while the results of density-independent PVAs would be relatively robust to some specific statements in relation to density dependence, they would be less consistent in relation to endangered populations susceptible to disease.

Nevertheless, managing schedules for endangered species should involve working with pathogens to decrease the threat of extinction and PVA including disease explicitly would be indispensable for enhancing the population persistence.

Chipman *et al.* [21] in an article entitled "Downside Risk of Wildlife Translocation", were among the first to indicate that in addition to translocations for conservation purposes, various other forms and means of actions involving translocations of wild mammals were increasing, producing negative consequences.

They reviewed and argued the challenges about restrictive normalizing for translocations in the USA, targeting the animals originated from the public nuisance wildlife control, and wildlife rehabilitators.

The authors questioned the practice of translocation in function of several negative outcomes such as, stress and death of relocated animals besides effects on resident fauna, conflicts with human interests and diseases spreading.

In addition it was highlighted that some types of translocations practices would make vulnerable the control or eradication of important wildlife diseases in North America, like the rabies in raccoons, coyotes, and foxes.

The different types of wildlife translocation described, included:

1) Unintentional:

Where animals that feed on human-generated waste could be transported inadvertently in garbage trucks from city to city or interstate.

For an example of unintentional translocation, it was referred the spreading of an enzootic raccoon variant of the rabies virus covering several states from United States caused by garbage relocation.

2) Interstate to supplement hunting:

Practiced by private hunt clubs of the United States that had been traditionally imported and released mesocarnivores coyote (*Canis latrans*), red fox (*Vulpes vulpes*), gray fox (*Urocyon cinereoargenteus*) and raccoons to enhance hunting opportunities.

As an example, cases of raccoon rabies enzootic were mentioned relating it spreading from North America north and southern portions of Ontario, reaching Quebec and New Brunswick, Canada.

In addition another case related to the translocation of coyotes from Texas to Florida for the same reason, could have resulted in a substantial geographic spread of a canine variant rabies.

3) By the public:

It was related that despite of the especially scarce information about the public handle wildlife without professional assistance.

It was mentioned a study carried out in 1990-91 that observed about 25% of the asked people had solved nuisance wildlife problems by themselves being 26% through live traps.

In addition, an informal inspection in the United States during 2004 and 2007 involving the cage trap market, it have showed a sales increasing from 10% -

100% in five years.

4) By nuisance control operators:

Considering the United States translocation have been commonly enjoyed to the control of both pest and nuisance wildlife.

According to the authors, this type of industry had grown substantially since the 1990s, accounting for most translocations of mesocarnivores in the country.

Table 2 was based on the results of two tables that were presented showing the top ten animals treated by Nuisance Wildlife Control Operators in Connecticut and New York respectively in 2000 and 2001-2002. Only mammalian species were included but even so, it shows how impacting that kind of translocation can be.

5) By rehabilitators:

The rehabilitators or custodians are unpaid authorized helpers who assist injured animals for further release after their recovery.

Although the effect of this practice on populations is undetermined, it could result in the release of animals in regions other than those in which they were rescued.

Besides, the effect of the release of animals after maintenance for several weeks in captivity could be comparable to the geographical translocation, even if the release had been made in the same place they were caught.

In relation to that topic number five, we presented Table 3 that was based on the results of Chipman *et al.* [21] and presents a list of the mammal species handled by Wildlife Rehabilitators in Connecticut in 2000, or by Nuisance Wildlife Control Operators in New York, October 200 I-September 2002 with their respective number of specimens.

**Table 2.** Mammals moved by Nuisance Wildlife Control Operators in Connecticut in 2000 as well as handled by Nuisance Wildlife Control Operators in New York, October 200 I-September 2002. Based on the results of Chipman R. *et al.* (2008) [21].

| Rank | Animals | Number of animals |
|---|---|---|
| 1 | Squirrel ("other") (Rodentia spp.) | 4.569 |
| 2 | Skunk (*Mephitis mephitis*) | 2.297 |
| 3 | Raccoon (*Procyon lotor*) | 1.864 |
| 4 | Woodchuck (*Marmota monax*) | 1.217 |
| 5 | Bats (Chiroptera spp.) | 924 |
| 6 | Opossum (*Didelphis virginiana*) | 507 |
| 7 | Moles (Insectivora spp.) | 165 |
| 8 | Chipmunk (*Tamias striatus*) | 68 |
| 9 | Feral cat (*Felis catus*) | 64 |
| 10 | Gray fox (*Urocyon cinereoargenteus*) | 24 |
| 11 | Coyote (*Canis latrans*) | 22 |
| 12 | Red fox (*Vulpes vulpes*) | 7 |

**Table 3.** Mammals species handled by Wildlife Rehabilitators in Connecticut in 2000, or Nuisance Wildlife Control Operators in New York, October 2001-September 2002 and the respective numbers of specimens.

| Order | Animals | Number of animals |
|---|---|---|
| 1 | Squirrel (Rodentia spp.) | 3.298 |
| 2 | Rabbits | 2.628 |
| 3 | Opossum (*Didelphis virginiana*) | 1.005 |
| 4 | Raccoon (*Procyon lotor*) | 602 |
| 5 | White-tailed deer (*Odocoileus virginianus*) | 342 |
| 6 | Skunk (*Mephitis mephitis*) | 167 |
| 7 | Red fox (*Vulpes vulpes*) | 59 |
| 8 | Gray fox (*Urocyon cinereoargenteus*) | 32 |
| 9 | Coyote (*Canis latrans*) | 10 |

Based on the results of Chipman R. *et al.* [21].

In conclusion, the authors indicated the great importance of Wildlife to the United States as resource and highlighted that the majority of translocated animals by people or public agents were because human-wildlife worries in urban and suburban habitats.

In function of anthropic action, the augmented accessibility of foodstuff and shelter would cause the increasing of certain animal species populations in those areas with high demographic density, aggravating nuisance wildlife problems and resulting in translocations.

Finally, it was suggested that because the risk of spreading diseases like rabies, chronic wasting disease, West Nile virus, and avian influenza, the euthanasia of nuisance animals instead of translocation would be an important alternative for protecting people, endangered species or pets as well as additional problems for homeowners neighboring the release places.

Emslie *et al.* [22] presented the First Edition of Guidelines for the *in situ* Re-introduction and Translocation of African and Asian Rhinoceros.

The scope of the guidelines was focused on translocations for conservation and rescue of rhinoceros species. The global objectives were growth and lifelong viability of those animals.

The guidelines were organized sequentially in four sections.

In the Section 1, was presented several points related to a pre-translocation phase.

So during the Pre-translocation, the actions that should be progressed included,

Planning and Management, Biological and Socio-Economic and Legal engagement. Encompassing the general viability and assessment, plans for promoting source populations growth, selection of donor and recipient areas as well as the source animals, planning and logistical coordination, personnel require-

ments, translocation, mortality risk, veterinary cares, socio-political considerations, costing etc.

Section 2 considered the execution of the translocation including, logistical and operational aspects of the capture, veterinary monitoring equipment for the captures and transportation, etc.

Section 3, the post-release period involved, intensive post-release follow up, veterinary care, continuing protection, monitoring and supervision, etc.

Finally, in Section 4 that would comprise an inventory of the mistakes and information acquired from previous translocations.

In addition, two annexes were also presented related to protocols for basic pre-reintroduction/translocation health screening and prophylaxis as well as the veterinary role in the investigation and post mortem procedures.

Considering the problem related to the disease risk and translocations, the authors stated the importance of veterinary knowledge for the planning and implementation of captures and translocations.

It was pointed out that the risks associated with transmission of infectious agents due to translocations existed and the health of the animals should be a priority.

Among the few available studies showing the risk of trypanosome infections on the rhinoceros from Africa, some were coincidently performed during translocations. Nevertheless, it was assumed that death risk would always be present nonetheless; it could be reduced using applicable procedures, medicines and knowledge.

The use of translocation could amplify population growth rates, maintaining long-term genetic conservation, increase range and number of populations. It could also have "strategic advantages", like expanding the capability of the wildlife populations to persist on natural disasters such as a Tsunami, disease etc. as well as avoiding subspecies extinction.

In the topic, identification of recipient areas as well as the dissimilarities in the conditions of donor and recipient places. It was stated that black rhino would apparently present a certain trypano-tolerance, nevertheless could develop disease under stress and/or immunosuppression conditions. It also could occur when they were precipitously exposed to infected vectors after they had been living in areas free of the parasite for long time.

According to the authors, regardless of the origin of the animals, they could adapt in a few weeks and show resistance to infection. This would be achieved by controlling the level of the host's exposure to the vector. Initially they should be exposed to low numbers of fly vectors and they would be never be introduced in areas with a high density of glossinid flies.

Based on the occurrence of differences in the susceptibility to *Trypanosoma brucei* infections observed in populations of white rhinoceros living in two distinct geographical areas of Africa, was suggested that these species would tend to adapt to subpopulations of the parasite where they had been living together for some time.

Conversely, it was highlighted that there was no indication that reducing the infection challenge would induce resistance. Besides it was also mentioned a case of translocated animals that had died because *Trypanosoma* infections, even after months of previous controlled exposure.

In the topic concerning wild vs. captive or semi-captive breeding, based on previous studies and on some data describing problems that occurred in intensive breeding programs for captive or semi-captive rhinos in Africa and the information that wild populations were more successful and less expensive, principally for Asian species.

It was proposed the fence using and protection of a suitable area that would promote better growth rate with possible lower cost. Disease risks should be considered on a case by case.

Some animals that intermittently leaved the protected areas invading adjacent farmland named stray-rhinos, they were common in the South Asia and consequently were potential targets for translocations and reintroduction into new areas. The authors showed the high risk of those animals carrying diseases, because their behavior frequent stress situations increased the risk.

In veterinary considerations, they were stated few general points around potential problems related health and disease.

It was considered that the knowledge on horse veterinary proceedings could mean as opportunities for the understanding of rhino diseases because their close relationship in the physiology, parasites, disease, response to drugs among others.

The term "biological package" introduced by Nettles in 1988 was remembered, so it was considered the translocation of an animal could be a movement of biological elements including endo- and ectoparasites possibly dangerous to other rhino populations and herbivores.

The problems related to the possibility of introducing microorganisms in the releasing site, as well as the risks of introduced animals acquire infections by local pathogens were reminded.

The use of healthy animals was pointed as prerequisite for a successful re-introduction, because they would have more possibilities of surviving in cases of stress, besides supposedly being more capable to adapt to their new habitat.

The necessity of qualified veterinarian assessing the translocation of captive or wild animals was stated for an effective evaluation of possible disease risks.

Thought the scarce information of rhino infections at that time, it was suggested that any chance to examine live and dead animals should include systematic studies and a complete biological sampling.

Trypanosomosis has been mentioned as a problem for rhino exposed through translocation into tsetse fly zones.

Considering anterior records about the higher pathogenicity of some *Trypanosoma* species in white rhinos when compared to black rhinos, it was indicated that this first species should not be translocated to areas of occurrence of those parasites.

Some records about the susceptibility of rhinos to *Babesia* and *Theileria* were also mentioned and one case of translocation after the animals have been vaccinated against *Babesia* was recorded as seemingly have been challenged with no side effect.

With respect to the two annexes above mentioned, in the first one entitled "Basic pre-reintroduction/translocation health screening protocols and prophylaxis". Several actions were proposed including: risk assessment, clinical evaluation, haematocrit, blood smear thick and thin and serum collection for stocking, occurrence disease, presence or absence of pathogens in source and recipient populations including sympatric species, endo- and ecto-parasitic load documenting and treating only if mandatory by international protocols or if absent in the recipient place, serology, vaccination for tetanus and other diseases, necropsy of any dead rhinos, eventual treatment of endo- and ecto-parasites with avermectin group of anthelmintics, enteric pathogen culture, *T. brucei* test.

In the second annex named "Summary protocol for veterinary investigation and post mortem of a rhino carcass" it was recorded a very important point the use of appropriate precautionary measures for contagious agents. In addition, it included some other conventional proceedings like, take capillary blood smear and serum collection if feasible, record the presence of ectoparasites, take complete series of tissue samples among others.

Hartley and Gill [23] published a study entitled "Assessment and mitigation processes for disease risks associated with wildlife management and conservation interventions".

The study described methods approved according the English laws for disease risk evaluation on wildlife conservation interventions.

They were sorted into four categories that could result respectively in five licensing categories: 1) no additional license conditions, 2) additional license conditions imposed by a wildlife advisor; 3) additional license conditions imposed by a government wildlife veterinarian; 4) a request for a qualitative veterinary risk assessment and 5) refusal of the license.

The Category 1 included the following premises: licensed killing of the animals with appropriate carcasses disposal, keeping animals into captivity inaccessible from free-ranging species and relocation of animals in the interior of their home range.

Rearing or trading captive animals with the purpose of not release were also considered to pose a negligible disease risk.

In the Category 2, it was showed some actions related to the capture of wild animals with subsequent releasing into their initial home range after short interval of captivity. Thus, activities like biological sampling and telemetry studies using wild caught animals and the liberation of recovered wildlife from the veterinary hospital were included in that category.

The time in captivity and the exposure to disease in the course of the intervention should be utilized for determining the disease risk.

The emphasis according the authors was hygiene and biosecurity, or veterinarian assertion that the animal is free of clinical signs of infectious diseases.

In regarding to that, we would suggest procedures more detailed, because for several parasites, when infecting their sylvatic hosts, the infections are subclinical in many cases being detected only by molecular tests.

The Category 3 encompassed interventions considered of likely high risk of disease introduction.

These should be forwarded to a government wildlife veterinarian for further appraisal. They would include solicitations for moving animals beyond their home range or species which specific concerns of disease.

In those cases, it should be proposed veterinary participation to ensure health assessments for quarantine, biosecurity and necropsy.

Apply, respectively, in cases of transfer of an animal far from its area of origin, the release of imported wildlife, as well as species with specific concerns related to diseases.

The probable impacts of diseases introduced by translocated or released wildlife on local wildlife populations, livestock or human beings should be considered to establish the diseases of concerns.

Although the UK was thought free of a number of important pathogens with wildlife reservoirs, according the authors the importance of the diseases of concern should be recorded to those that would have the highest impact on wildlife populations as well as in the human health or on the economy.

When possible routes of exposure and the most troubling diseases associated with the proposed licensed action would have been identified, the veterinarian would consider mitigation measures.

It was mentioned that frequently just simple generic precautions such as biosecurity and hygiene practices or clinical inspection were performed by veterinarian before release and sporadically specific pathogen assays were demanded.

The Category 4 of disease risk should be applied just in extraordinary situations principally in advance of licensing official reintroduction programs. It should have been requested a full veterinary risk assessment, containing risk managing methods and the course of action should be borne by the entrants.

It was stimulated that any such project should have experienced veterinary supervision during quarantine regimes, animal naming, pre- and post-release disease surveillance, postmortem examination procedures and medical records.

The entire process should also conform to the International Union for Conservation of Nature and Natural Resources (IUCN) Guidelines for Re-introductions (IUCN/Species Survival Commission [SSC] Re-introduction Specialist Group 1998)

Any demands should be considered by a review panel of senior officials from Natural England and Defra as well as by an autonomous veterinary review.

Kock *et al.* [24] described some disease risks associated with the translocation of wildlife, reminded the definition of translocation in field of conservation as the intentional transfer of living organisms from one geographic area to a new,

meaning the establishing, re-establishing or supplementing a population.

They pointed that the risk of disease introduction because wildlife trade or translocation for the companion animal would be possibly of greater than the risk posed by animals translocated for sporting or conservation purposes.

It was remembered that the risks involved on translocations, would depend on a variety of factors including the epidemiological conditions in the area where the animals came as well as in the destination or release place.

According the authors, the animals born or raised in captivity like zoological gardens, farms and breeding centers could represent the greatest risk, because under natural conditions the epidemiological processes besides the natural selection would decrease the probability of pathogen survival.

Nevertheless an important point was also mentioned, those animals could present asymptomatic infections including with latent pathogens to other species.

It was also recorded that the risk of a translocated animal introduce different pathogens into the release area affecting the immunologically naïve fauna in addition the concept proposed Nettles in 1988 that "a translocated animal is not the representative of a single species but is rather a biological package".

We presented further down **Table 4** and **Table 5** based on the results of Kock *et al.* [24] and showing respectively examples of wild mammal diseases introduced or encountered in release areas after wildlife translocations.

Subsequently, a proposal of available measures to be applied in actions related to wildlife translocations was presented.

Those measures included, schedules for minimizing the risks, through veterinary intervention at the source of the release or among founder stock comprehending of laboratory detection procedures, clinical haematology, screening for

**Table 4.** Wild mammals species origin and places where diseases have been introduced after their translocation.

| Species | Origin | Disease | Microorganism | Destination | Concerned species |
|---|---|---|---|---|---|
| Zebra (*Equus burchelli*) | Namibia | African horse sickness | Orbivirus | Spain | Domestic equids |
| Racoon (*Procyon lotor*) | Texas | Parvoviral enteritis | parvovirus | West Virginia | Local raccoons (*Procyon lotor*) |
| Racoon (*Procyon lotor*) | Florida | Rabies | *lyssavirus* | Pennsylvania, | Skunks (*Mephitis mephitis*), |
| Skunks (*Mephitis mephitis*), | Florida | Rabies | *lyssavirus* | Virginia and Maryland | local racoons |
| Wapiti (*Carves elaphus*) | United States | Giant liver fluke | *Fascioloides magna* | Italy | European ungulates |
| Bighorn sheep (*Ovis canadensis*) | Arizona | Viral pneumonia | RSV | New Mexico | Local bighorns |
| Plains bison (*Bison bison*) | Montana | Tuberculosis, brucellosis | *Brucella* abortus *Mycobacterium bovis* | Canada | Wood bison (*B. bison athabascae*) |
| Hare (*Lepus europaeus*) | Hungary and former Czechoslovakia | Brucellosis | *Brucella suis biovar* | Switzerland and Italy | Domestic animals, humans |

Based on the results of Kock *et al.* [24].

**Table 5.** Diseases encountered at release areas by translocated wild mammals. Based on the results of Kock R.A. *et al.* [24].

| Species | Origin | Disease | *Microorganism* | Destination | Concerned species |
|---|---|---|---|---|---|
| Bongo (*Tragelaphus eurycerus isaaci*) | United States | Babesiosis | *Babesia* spp | Kenya | Local artiodactyls |
| Roan antelope (*Hippotragus equinus*) | Namibia | Theileriosis | *Theileria spp* | Swaziland | Tick vectors |
| Sable antelope (*Hippotragus niger*) | Namibia | Babesiosis | *Babesia spp* | South Africa | Tick vectors |
| Bighorn sheep (*Ovis canadensis*) | United States | Babesiosis | *Babesia spp* | United States | Tick vectors |
| mule deer (*Odocoileus hemionus*) | United States | Babesiosis | *Babesia spp* | United States | Tick vectors |
| Bighorn sheep (*Ovis canadensis* | United States | Pasteurellosis | *Pasteurella spp* | United States | Sheep |
| Eastern woodrats (*Neotoma floridana*) | United States | *Baylisascaris infestation* | *Baylisascaris procyonis* | New York | Racoons |
| Black rhino (*Diceros bicornis*) | South Africa, Kenya | Babesiosis, theileriosis, trypanosomosis | *Babesia*, *Theileria and Trypanosoma* | Masai Mara, Tsavo, Meru, Kenya; Meru, Kenya; Ngorongoro, Tanzania | Tick and tsetse vectors |
| white rhino (*Ceratotherium simum*) | South Africa, Kenya | Babesiosis, theileriosis, trypanosomosis | *Babesia*, *Theileria and Trypanosoma* | Masai Mara, Tsavo, Meru, Kenya; Meru, Kenya; Ngorongoro, Tanzania | Tick and tsetse vectors |
| Koala (*Phascolarctos cinereus*) | Victoria, Australia | Tick paralysis | *Ixodes spp.* | Victoria, Australia | Toxic agent in the saliva |
| Caribou (*Rangifer tarandus*) | Eastern United States and Quebec | Cerebrospinal nematodosis | *Elaphostrongylus rangiferi* | Ontario and Nova Scotia Canada | White-tailed deer (*Odocoileus virginianus* |
| Arabian oryx (*Oryx leucoryx*) | United States | Botulism | *Clostridium* | Oman | Enzootic in Oman |
| Muskrat (*Ondatra zibethicus*) | United States Canada | Tularemia | *Francisella tularensis* | Soviet Union | Water voles (*Arvicola terrestris* |
| Brush-tailed possum (*Trichosurus vulpecula*) | Tasmania | Bovine tuberculosis | *Mycobacterium bovis* | New Zealand | Deer, wild pigs, etc |
| Golden lion tamarin (*Leontopithecus rosalia*) | United States | American trypanosomiasis | *Trypanosoma cruzi* | South-eastern Brazil | Local fauna |

haemoparasites through blood smear for haemoparasites identification, analyses of antibody detection among others.

Furthermore, for verifying if some animal would be probably infected with a specific pathogen an assortment of more specific tests like, ELISA, PCR and immunohistochemistry they should be carried out.

A group of more actions completed the proposal such as, veterinary supervising at the supposed release site, pre-release planning, interpretation of survey and screening results, prophylactic vaccination, post-release health intensive care and cryopreserved germplasm, among others.

The authors concluded that whatsoever the objective of translocation there

could be at all times a substantial disease risk and vectors or pathogens could be transmitted among translocated animals or to recipient fauna.

The human behavior was pointed as an underestimated threat because of the great quantity of mammal species moved with minor or no health constraints all over the world.

Moreover in 2010, the IUCN [25] published a very useful Training Manual on Wildlife Diseases and Surveillance, produced from the Workshop for OIE National Focal Points for Wildlife by the World Organization for Animal Health (OIE).

Different from the above mentioned IUCN Training Manual published in 2009, in that last one it was addressed specific points related to the wildlife pathogens and diseases.

It started with a definition of "Wildlife" concerned with pathogens and diseases of mammals and birds described as wild animals.

Then were presented some aspects related to socio-economic significance of pathogens and diseases of those wild animals that could affect the health of human and domestic animals, but also could produce significant impact on the populations of wild animals.

In this section were listed some wildlife zoonotic diseases or pathogens and those the related to mammals were the following: HIV, Rabies, Hanta viruses, Chagas' disease, Yellow fever, Leishmaniasis, Brucellosis, Tuberculosis, Leptospirosis, Anthrax, Plague, Trichinellosis, Nipah virus, Ebola virus and Monkeypox.

In that list we could include some others important zoonosis like, Toxoplasmose, angiostrogiliasis, Shistosomosis, chikungunya, Mayaro virus, dengue, Rocky Mountain spotted fever, Bartonella, Lyme disease and others.

Among the examples of pathogens in wild animals may affect the health of domestic mammals were included: Anthrax, Bovine tuberculosis, Foot-and-mouth disease, Leptospirosis, Rabies, Myxomatosis, Chronic waste disease, Classical and African swine fevers, Brucellosis, Venezuelan equine encephalitis, Blue tongue and Epizootic hemorrhagic disease.

It was also presented considerations about the ecology of pathogens and diseases, emerging diseases and wildlife, pathogen transmission, reservoirs of infectious pathogens, measure of pathogen transmission, manage pathogens and diseases in wild animals, national wildlife disease programs and surveillance.

In the section "Reservoirs of infectious pathogens", the definition for pathogen reservoir was "one or more epidemiologically connected populations or environments in which the pathogen can be permanently maintained and from which infection is transmitted to the defined target population".

Nevertheless, it is important to highlight that several epidemiological studies have been considering also the concept of reservoir hosts in relation to mammal species and some parasitic protozoa, because certain particular species of hosts looks to present a metabolic relationship with determined parasite species originated after a longer co-evolution process. The relationship between those reser-

voir hosts and the parasites, in general presents an equilibrium, the infections are in general sub-patent and sub-clinical. So, those species particularly serve as sources of infection for the vectors. Ex: *Trypanosoma cruzi* and *Leishmania* when infecting the opossum.

In the components of national wildlife disease programs, a very important point was referred in relation to governmental policies, regulations and programs. It would be fundamental to make possible suitable achievement issues in relation to wild animals and pathogens. It was highlighted that countries not prepared to deal which that situations could be at risk of the negative effects from those health and disease concerns.

They considered wild animal pathogen assessment essential to animal health management and proposed a constant search and vigilance for pathogens in wildlife and potential diseases they could cause, collecting data and achieving systematic analysis.

That surveillance results should comprises communication of the information gathered to the people, agencies and institutes that could need information.

Accordingly, those surveillance programs should have a number of different actions, like, the detection of dead or diseased wild animals, collection of samples from wild populations, pathogens characterization and diseases diagnosis through laboratory assays, data computerized treatment, analysis and reporting as well as the production of maps, statistics and conferences.

They stated that wide-ranging surveillance for wildlife pathogens should starts with the detection of those microorganisms in sick or dead wild animals. Such work should be implemented by a network of qualified professionals, for collecting and processing biological samples for further diagnostic tests.

Finally they showed two appendices respectively related to "Terms of Reference for the OIE National Focal Point on Wildlife" and a suggestion of Project for small groups for wildlife pathogen and disease surveillance.

The authors stated that wide-ranging surveillance for wildlife pathogens should starts with the detection of those microorganisms in sick or dead wild animals. Nevertheless, we think that before starts any fieldwork, broad reviews on the scientific literature should be of great importance, seeing that actually for most zoonosis there is great number of publications.

We agree that the collection of biological samples for further utilization in diagnostic tests is notoriously important and in respect to that, we have been suggesting that animals hit by vehicles on the roads could represent a very a significant source of biological samples.

Campbell and VerCauteren [26] in a study entitled "Diseases and Parasites of White-tailed Deer" they presented a panel with the objective of providing a synopsis encompassing, parasites, prion, viral, bacterial and rickettsial diseases.

Among parasites were included protozoan of the genera *Toxoplasma*, *Babesia* and *Theileria*, Helminths were liver fluke, large lungworm, large stomach worm, meningeal worm, arterial worm, abdominal worm and larval tap worm.

The prion sickness was the Chronic wasting disease (CWD), rickettsial disease was anaplasmosis and the bacterial were anthrax, dermatophilosis, brain/intracranial abscesses, bovine tuberculosis, Johne's Disease/paratuberculosis, leptospirosis, salmonella and Lyme disease.

The viral diseases were hemorrhagic disease, cutaneous fibroma and other viruses including some arboviruses.

It was highlighted the concerning in relation to the presence of CWD in both captive and free-ranging white-tailed deer and other cervids.

It could mean a critical management problem because of the long incubation period, negligible early clinical signs, life-threatening infectious agent, environmental contamination, multiple modes of transmission and a 100% mortality.

The measures suggested for decelerating the spreading were localized population reduction, regulating translocation and prohibition of baiting and feeding.

According the authors the meningeal worms should be also considered a concerning subject for natural resource managers and biologists that would assume translocation activities. The life cycle complexity of the *Parelaphostrongylus tenuis* with mollusks as intermediate hosts could be an additional aggravating factor and a significant threat to all native cervids.

Finally, they suggested the adoption of the guidelines of Corn and Nettles (2001) by biologists and managers that could be involved in cervids translocation.

Trinkel *et al.* [27] recorded a very interesting experimental test where translocations were proceeded for combating bovine tuberculosis (BT) in a lion population with increased susceptibility to for that disease caused by inbreeding.

They demonstrated that while 15% of the native population died because BT, on the other hand less than 2% of the translocated animals died for the same reason.

Besides, they also recorded there were no significant differences on the antibody prevalence to six feline viruses among native and translocated lions, as well as offspring. It was suggested that these feline viruses likely presented no effect on the clinical health of the animals.

The authors concluded that the translocation of those animals without prior studying of their health status could give rise to unexpected results and management of population genetics through supplementation could effectively prevent pressures on the population's persistence.

Nevertheless, it was stated that the absence of BT deaths in the translocated animals and their offspring could be because of the long incubation period of the microorganism that can remain dormant for years and eventually reactivate.

Although they have been recorded, there were no significant differences on the antibody prevalence to six feline viruses among native and translocated lions. Based on the results presented it is very likely that on cases of feline coronavirus as well as feline calicivirus the differences were significant. Considering that for coronavirus the percentage of positives on the natives were 3% and among the

translocated ones was 13% and 21% and for calicivirus, the group translocated in 2006 none of the animals had specific antibodies to Calicivirus.

In 2013, the IUCN [28] published new "Guidelines for Reintroductions and Other Conservation Transactions", they were comprised of nine sections, ranging from introduction and scope of guidelines, deciding when translocation is an acceptable option, until Monitoring and continuing management and dissemination of information.

In relation to disease and translocations, in the section 6 named risk assessment, one of the main categories was the disease risk.

Considered that no translocated organisms could not be entirely free of infections and the risk of disease spreading would ever exist. It should be assessed at the beginning of the planning stage, evaluating expected probability of occurrence and gravity of negative effects of pathogens as well as the risk of spreading and should be reviewed periodically.

One important aspect presented was related to the idea that viability valuation should incorporate the balance of the conservation benefit against the costs and risks of both the translocation and different conservation actions.

Translocation would interchange with human interests, than socio-economic and political factors should be essential to translocation achievability and planning. These actions would need efficient multi-disciplinary staff, with technical and social knowledge that could act for all interests.

In 2014, OIE and IUCN [29] co-published guidelines directed to diseases risk analysis of the wildlife.

Disease risk analysis (DRA) was pointed as a tool for investigating the risks of introduction, emergence or re-emergence of a disease in a population. It could also help the assessing the risk of disease transmission between different species.

According the authors that tool had been used based on the concept that the disease risk could be triggered by a new or probable action, such as the movement of species into a new territory. Besides it was suggested the aim of DRA was provide effective and low cost prevention and mitigation plans.

DRA has been progressively applied, in agronomic business, species reintroduction or translocation, but also in human-wildlife and domestic animal interactions with a quite broader applicability.

Five steps in the process of disease risk analysis were proposed as summarized below:

1) Problem description for defining the circumstances and determine the objectives of the DRA as well as make query, assert conjectures and restrictions and stipulate the adequate risk degree.

One of the questions proposed was about the type DRA that would be needed for applying to solve each specific situation.

2) Hazard identification for classifying the health hazards in "infectious" or "noninfectious". Categorize each threat taking into account the likely of direct and indirect outcomes indicating which hazards should be of full risk appraisal.

The issues raised were related to what could cause the disease, how it might

happen and the likely extent of the problem.

3) Risk assessment for ranking the hazards in a descending order of precedence and evaluate each risk individually for the probability of disease introduction in the new area, the possible level of the species exposition and the probable consequences in case of disease dispersion.

In this case, the question presented was about the probability and also the effects of a detected threat happen in a recognized pathway or event.

4) Risk management for reconsidering the possibilities of potential risk reduction or controlling as well as appraise the probable consequences.

The questioning has been related to the probable actions for reducing the probability of occurring a risky incident and diminishing the consequences if it would have happen.

5) Implementation and review for preparing a strategy of action and contingency as well as ascertain the procedure and schedules for the supervising, assessing and assessment of risk management.

That action should result in a well-defined knowledge about the question for supporting the DRA improvement.

The questions were about the criteria of selection of risk management actions that should be applied, their assessment considering if the objectives were reached and the possibilities of its improvement.

Besides the five interconnected steps, in a schematic view occupying a central point, the "Risk communication" makes bridges interconnecting all the components together.

One more aspect addressed was the representation of the eco-epidemiological picture of Ebola and Nipah viruses and Chytridiomycosis in addition to the impact of Diclofenac using. The scheme showed the relationship among, humans, peri-domestic wildlife and livestock inside the human landscape and participation of the neighboring wildlife, composing the natural environment.

They concluded proposing that, disease risk analysis of wildlife should work in concert with other agencies and that different presentations of DRA have been used by various areas like, public health, agriculture, trade, the pharmaceutical industry and wildlife conservation.

The IUCN highlighted that DRA should be applied in all segments related to wildlife disease, strengthening the concept of "One Health" that acknowledges the interconnection among the health of people, animals and the environment.

Still in 2014, Jakob-Hoff *et al.* [30] in an OIE and IUCN co-publication prepared a "Manual of Procedures for Wild Animal Disease Risk Analysis". In the first part of this manual, the stages of the process of disease risk analysis (DRA) were presented; in fact, this subject was also stated in the "Guidelines for Risk Analysis of Wildlife Diseases.

After the introduction and a brief history of disease risk analysis, were presented key concepts for wildlife disease risk analysis including, risk, disease, disease causes and impacts, objectivity, proportionality, the 'precautionary principle and others.

In following, a detailed description about the planning and conducting a wildlife disease risk analysis was presented showing several practical situations.

Were included statements about collaboration, technical, social and political considerations, challenges in wildlife disease risk analysis, etc.

Among other topics asserted were comprised, risk of communication, problem description, hazard identification, risk assessment, risk management, implementation and review and to close a checklist for conducting a wildlife translocation disease risk analysis.

It is important to highlight, in spite of a very well elaborated manual, the authors even so they signaled the impossibility to reverse habitat loss and extinction or preventing the emergence or resurgence of diseases in such globalized world.

Therefore, the integration among biodiversity conservation, biosecurity, domestic animal health as well as public health, is fundamental when addressing in conditions when wildlife disease is a human life-threatening issue.

In relation to the public health, a very important point presented was the suggestion of inclusion of doctors belonging that area on the DRAs. In function their expertise in diseases prevention and promotion of human health besides the possibility of instructing medical and veterinary practitioners.

Because the increasing contacts between people and wildlife, they suggested that DRAs should include the possibility of zoonotic disease transfer and doctors in public health could give recommendation on measures for the risks management.

Finally, twenty-two very useful tools for wildlife disease risk analysis were presented.

They were: Disease Risk Assessment Tool (DRAT), Visual system-level simulation modeling: Stella and Vensim, Disease Risk Analysis Worksheet (DRA Worksheet), Paired ranking for hazard Prioritizing, Graphical models, Decision trees, Influence diagrams, Fault trees, Concept Maps (Cmap), Geographic Information Systems (GIS), OIE Handbook, @Risk, OUTBREAK, PopTools, Formal elicitation of expert opinion, Netica, Precision Tree, Vortex, RAMAS and Risk communication plan template.

Additionally, it was also exemplified the use of some those tools and incorporated eight appendices, ten boxes, fifty-one figures and nineteen tables showing how complex could be the DRA and the importance of a multidisciplinary approaching to carry it out.

In 2015, the OIE World Organization for Animal Health published a fact sheet entitled "Wildlife Diseases" [31] that was produced basically for presenting the WAHIS interface, a World Animals Health Information Database produced through information mostly obtained from veterinary services.

Based on that wild animals could be targets or reservoirs for microorganisms able of infecting other animals and human, it was considered that the wildlife disease monitoring, prevention and control were decisive aspects for biodiversity

preservation as well as for public and animal health.

According the authors an increased spreading of pathogenic organisms had been occurring in function of several factors including anthropic action, climate change, globalization, demographic evolution and new human social behaviors.

Intensified trade around the world had provided more chances of infectious agents combine, circulate in different species and exchange genetic material with the potential development of new killer pathogens.

In relation of the WAHIS in our view, it may considered a very important tool for the world animals health, nevertheless as already above mentioned, it is a health information database basically produced through information obtained from veterinary services.

We think the WAHIS should also include information from other sources besides the veterinary services. In the scientific literature, there is vast number of papers from diverse groups that have been studding diseases from a great number of animal species.

Additionally, the information should be more contextualized, for example: in the WAHIS wild interface, the section affected species, where it should be observed disease/infection presence occurrence by codes for a chosen family (ies) and species. The diseases related to Didelphidae in the table related to disease/infection presence by species from 2008 to 2018, it show only one case of infection with *Leptospira interogans ssp* and other of salmonellosis caused by *S. enterica*, respectively in *Didelphis virginiana* (Virginia Opossum) in Colombia and *Didelphis aurita* (Big-eared Opossum) in Netherlands.

As there is no additional information in the table, it could be assumed that those data were originated from zoo animals, because the species *Didelphis virginiana* do not occur in Colombia neither the *Didelphis aurita* (the Black-eared Opossum) in Netherlands.

The Didelphidae is a family of New World marsupials and the unique representative belonging that family of the genus *Didelphis* that occurs in Colombia is the *D. marsupialis.*

In addition to those significant reports that showed seemingly cases of accidental infections with *Leptospira and Salmonella*, there are numerous records equally relevant that could be included in the table.

There are many studies relating to several genera of the Didelphidae family and their close relationship with some representative of the Trypasomatidae family.

A number of species of the *Didelphis* genus have been fully described as important reservoir hosts of *Trypanosoma* and *Leishmania*, playing essential roles on the eco-epidemiology of the diseases caused by those parasitic protozoa in both sylvatic and peridomestic transmission cycles.

The *Didelphis* (common opossum) for example, it is the unique mammal host described until now where the *Trypanosoma cruzi* can complete its whole biological cycle presenting all developmental forms observed in both, the mammals

reservoirs and the triatomine insect vectors. Soon the parasite in the *Didelphis* can develop inside of muscle and nerve cells as normally do in all mammals or extracellularly in the lumen of scent glands, performing the cycle correspondent to that occur in the insect gut.

It is important to highlight that the forms of the parasite may be eliminated together the scent glands content what the animal do under stress situations. Actually, like the metacyclic forms excreted by the triatomine bugs those expelled by the opossum can equally be potentially infective to other mammals included man.

In 2017 Hartley and Sainsbury [32] in a paper entitled "Methods of Disease Risk Analysis in Wildlife Translocations for Conservation Purposes" they presented results related to the Zoological Society of London's Disease Risk Analysis and Health Surveillance (DRAHS) project.

It has been operating for 25 years, in partnership with Natural England and non-governmental organizations, to assess and respond to disease risks associated with interventions undertaken for the national species recovery program for native wildlife.

They recalled the risks of wildlife translocations and the inherent disease impacts that could cause broad effects involving government, farmers, local residents and businesses.

It was exemplified by the case of an unofficial introduction of European beavers and the *risk of introducing of the Echinococcus multilocularis* to the UK.

They also pointed different aspects related to translocations of species from ex situ populations and the potential disease risks. Those aspects included, animals with asymptomatic infections carrying pathogenic microorganisms to the new habitat, the exposition to exotic infective agents and the mixture of species from unrelated geographic regions, the potential stress resulting in immunosuppression and the absence of acquired immunity or resistance to the infectious.

As examples for those potential disease risks were mentioned the cases of hazel dormice that were exposed to a supposed novel cestode species in captivity prior to reintroduction and red squirrels (*Sciurus vulgaris*) reintroduced that were exposed to a squirrel poxvirus (harboured by an alien invasive grey squirrel, (*Sciurus carolinensis*) resulting in a severe squirrelpox disease outbreak. Both cases occurred in England.

Afterward, were made several considerations about the meaning of disease risk analysis, its development, different approaches and modifications for wildlife translocation, expertise involved, information required, quantitative versus qualitative analysis, uncertainty and subjectivity, disease risk management and finally the risk analysis as a tool for decision making.

Among to different approaches and modifications for wildlife translocation it was indicated that even when concentrated only on threatened species, there were several possibilities for making use of disease risk analysis like, preceding the reintroduction program, because a specific disease diagnosed in the course of

a project or an epidemiological search of unidentified disease concentrated in a determined species.

A table was presented showing several examples of how DRA, disease risk management (DRM), and post-release health surveillance (PRHS) had been incorporated into monitoring disease health and translocation of species covered by the DRAHS project.

Concerning the expertise involved, as already stated in previous studies, a necessity of a multidisciplinary team was indicated as very important.

In quantitative versus qualitative analysis, according the authors in function of the great scarcity of numerical data related to wildlife populations, like prevalence of infection, incubation period, duration of infection, and the size and distribution. The qualitative risk assessment could be probably as accurate as the quantitative method in wildlife translocation.

The advantage of the risk assessment when presented under a qualitative approach was the possibility of working with plain language and logic to be more comprehensible by a wider range of participants and decision makers.

Concerning to the uncertainty and subjectivity, it was highlighted the importance of stating the areas and the range of the uncertainty as well estimates risks, mainly in the early phases of assessment when supposedly the uncertainties could be large and the data scarce.

Based on the lack of mathematical or modelling studies directed to uncertainty, it was suggested the use of the information gap theory proposed by Ben-Haim (2001), which comprises mathematical development model, performance constraint and a model for uncertainty.

Disease risk management was described as a process of identifying measures that could be applied to the problem that would reduce the risk of disease. Schedules of risk management also would support the classifying of threats and redefine the suitable risk levels.

In risk analysis as a tool for decision-making, Hartley and Sainsbury mentioned Wooldridge 2000 when considering it as a progressive assignment employing facts and records combined with the thoughts and assessments from a wide-ranging of standpoints.

According to the authors, the determining of what could be considered as an acceptable risk constitutes one of the most difficult problems faced by decision-makers. Because some level of risk could be always predictable and the choice usually would involves societal or political decision.

Thus in respect to wildlife translocation, besides the disease risk analysis, financial costs, public support, political approval and stakeholder endorsement could be other providers.

In conclusion, they related that Wildlife disease risk analysis processes have been developing but even so, there were many questions for addressing yet.

In 2018, Mengak [33] in a paper entitled "Wildlife Translocation" discussed a very important point related to translocations and the risk of disease spreading,

the fate of animals implicated in human-wildlife conflicts.

It was recorded the concerns of scientists, wildlife managers, and public health professionals in relation the spread of disease and translocation of wild animals.

Once again, it was remembered that animals moved could carrier worms, ticks, fleas, viruses, bacteria, and other parasites. As an example was recorded, the case of a raccoon strain of rabies virus originated from raccoons from Florida (USA) and were introduced into the Mid-Atlantic and Northeastern states after translocations. Actually, even when moving the animals for short distances the concern would be well founded.

Other diseases including, plague, chronic wasting disease, pneumonia, tuberculosis and brucellosis, tick paralysis, botulism, tularemia, bovine tuberculosis, and trypanosomiasis were also associated to wildlife translocations.

Human exposure to diseases, for example, homeowners or others who would transport wildlife by exposing themselves and others at risk was also considered a concern.

In conclusion, Mengak [33] asserted that both professional and public opinion about managing wildlife and wildlife nuisance problems have been changed because certain wild animal species have been becoming more abundant.

Translocation in spite of usually been considered as humanitarian, harmless and effective, the wildlife professionals would not agree with the use of that technics, with exception of large carnivores where management options are limited to either translocation or euthanasia.

Actually, translocation for solving wildlife nuisance problems should be seldom proposed because several reasons like, animal stress, potential handler lesion, risk of moving a disease among others.

Instead, other measures should be taken and wildlife professionals should assist enlightening the public about alternative control measures, such as habitat alteration, exclusion, scare devices, repellents, and euthanasia.

They would be perceptive to changing public feelings and clarify why euthanasia would be the most reasonable choice when nonlethal methods are not achievable.

In 2019, one of the most recent and significant publication related to disease risk on wildlife translocations are the "Guidelines for the management of confiscated live organisms presented by IUCN, edited by Neil Maddison [34].

These guidelines presented a broad approach, including plants and animals, considering the importance of effective management methods to make the best use of the role of conservation and individual well-being.

Due to the need to promote a policy formulation process for wildlife management. It was emphasized, the importance of preventing the extinction of species in addition to safeguarding the health of each single animal prioritizing risk assessment for both, confiscated animals and for the wildlife that lives in areas where they could be translocated.

The spread of diseases from released animals caused by incorrect management

was considered as one of the primary risks for preventing of biodiversity loss.

A very important aspect was also presented related to taking of a proactive approach in order to make sure necessary information for the decision-making. It was suggested the development of consultative networks by the confiscating authorities that should comprise experts including:

1) Specialists in taxonomy to enable rapid and accurate identification to species/subspecies level.

2) Medical and veterinary team on human and animal health, and quarantine.

3) Professionals in wildlife rescue, husbandry and animal behavior.

4) Legal skill.

5) Logistical for advising on holding and transport.

6) Wildlife rescue/rehabilitation centers.

7) Zoo consultants and associations, and sanctuaries.

8) World Organization for Animal Health (OIE) focal points.

9) Government/university veterinary departments.

10) In-country CITES Management and Scientific Authorities.

11) In-country wildlife crime enforcement and border authorities.

The Guidelines In respect to action planning among the immediate short-term cares, it is emphasized the importance of confiscated organisms being immediately placed into quarantine that may vary depending on the species and situations.

Another important point stated was the disease transmission risks to humans and other organisms belonging the same or different species while in transit, holding or translocation.

The risks of disease transmission to humans and other organisms belonging the same or different species while in transit, holding or translocation were considered as well as the euthanasia that was referred as "the humane ending of an animal's life for the intention of preventing further suffering of an injured and/or sick animal."

In those cases of euthanasia, we suggest that all the material derived from the animals should be available for research. It would contribute directly to a pool of records about important species and the major infectious agents related to them.

It could be of great importance, taking into account that in several situations euthanasia is unfortunately the only option even for animals included in the extinction risk list. Actually, any sample collected from those animals may contribute with valuable information.

One more aspect mentioned directly associated risks of disease transmission, was the wildlife trading in view of a direct correlation between the increasing of wildlife confiscation and illegal trade in addition to a better knowledge and understanding on the part of the competent authorities.

It was assumed these guidelines are offered to help confiscation authorities make decisions in view of the notorious impossibilities of preventing the illegal trade in wild animals and the difficult decisions that they have to take concerning this problem.

Concerning to the wildlife trade, Can *et al.* [35] also highlighted the potential for spreading of zoonotic diseases.

Zoonosis are causing millions of deaths and just look at known cases of Ebola or Severe acute respiratory syndrome (SARS) that have been provoking global impacts.

Actually, wildlife trade either legal or not, it may represent risks to human health seeing that pathogens in their host they do not care about the way they are negotiated, legally or illegally.

There are several motives associated to, conservation, animal health and ethics to be concerned about the regulation of wildlife trade. Nevertheless, the pathogens responsible for emerging zoonosis, they should not be underestimated.

## 2. Discussion

Indeed, after presented how the procedures related to wildlife translocation and disease risk assessing have being evolving with the production of several protocols and guidelines.

Noticeably, the rules directed to conservation purpose are at present the best stablished.

Nevertheless as recorded by Chipman *et al.* [21] there are other types of actions involving translocations, including, by the public, nuisance control operators, rehabilitators and others.

In reality the relocation of wildlife have been needed more and more due to wildlife captured illegally and seized by authorities, sick or hit on roads, victims of anthropogenic environmental disasters and rescued from areas disturbed by major engineering projects, such as highways or power plants.

All those factors together with the scanty actions developed in some places directed to avoid disease spreading through wildlife translocation make that problem much more complex.

Even in conservation actions, it may be very difficult preventing adverse effects.

In fact, reintroducing an animal in the wild, ensuring its health, and further avoiding the introduction of some exotic species of parasites, can be a very difficult task.

There are several parasites such as the *Trypanosoma cruzi* that present different lineages that can circulate individually with different geographical distribution patterns, even in close fragments of the same forest [36].

As well *Leishmania* that can perform a discontinuous transmission pattern and even in circumscribed habitats may exist small areas corresponding to "hot spots" where the risk of parasite transmission is very high, surround by low risk places [37].

In addition, in several situations it is difficult the determining of what diseases must be tested for each species, because it can, change depending on the place where they dwelt that is fundamental for the diagnostics of certain endemic dis-

eases.

It must also be taken into account that in many diseases there is not enough information about the evolution and potential pathogenicity for a great number of species.

In addition, there is no available reagent to proceed diagnostic test for several of them. Even in those infections that could be easily diagnosed by a dipstick test, the data on the treatment or prevention, are either scarce or nonexistent.

It is important to highlight that a great number of microorganisms related to infectious diseases, have been co-evolving with their natural host species since millions of years ago, like *Trypanosoma* or *Leishmania* that have being evolving with their sylvatic mammal hosts since the existence of Gondwana supercontinent.

Indeed, it must be expected that sylvatic animals will probably be infected with a great number of parasites, which in many cases are also responsible for pathogenic human diseases.

As an example, we could mention the lion tamarins they are small New World primates belonging the genus *Leontopithecus* that is composed of four species: *L. rosalia*, *L. chrysomelas*, *L. chrysopygus and L. caissara.*

This genus is endemic from Brazil living in the Atlantic rain forest, in 2003 the golden lion tamarin (*Leontopithecus rosalia*) was down listed to endangered from Critically Endangered on the IUCN Red List following the black lion tamarin (*Leontopithecus chrysopygus*). It was achieved after three decades of conservation efforts involving numerous institutions.

It was considered by IUCN that populations of both animals have been considered well-protected but continue very small, indicating a necessity for reforestation to provide new habitat.

According to May and Lyles [5] of the 26 animals reintroduced in the native habitat in Poço das Antas Biological Reserve (Brazil), after about two years, only five were alive and disease was the leading cause of death.

Correspondingly, several other studies where carried out on the same place involving *Trypanosoma cruzi* infection on the populations of lion tamarins that are considered as one of the species that are reservoir hosts of this protozoan, the etiological agent of Chagas' disease. [38]

Lisboa *et al.* [39] analyzed the *Trypanosoma cruzi* infection in *Leontopithecus rosalia*.

From 118 lion tamarins composing 21 groups varying to three to eleven animals respectively, 52% presented positive serological titers and the parasite was isolated from 38 specimens. No patent parasitemia have been observed indicating that the indirect diagnostic methods would be more effective in similar cases.

Nevertheless, some animals formerly free from *T. cruzi* infection, in a period of some months showed serum conversion and positive hemoculture, indicating the occurrence of a sylvatic cycle and active transmission.

Lisboa *et al.* [36], described distinct patterns of *T. cruzi* infection among dif-

ferent populations of *L. rosalia* and concluded that the parasitaemia of infected tamarins from the above mentioned reserve, is higher than that of tamarins from the other studied forest fragments.

They winnowed three hypotheses for explaining it: 1) reinfection, 2) concomitant infection by other parasites and 3) improper management conditions of this forest fragment. Nevertheless, the possibilities reinfection were considered irrelevant based on haemocultures and experimental infections.

In our opinion, it is likely that has occurred insect vectors dispersion, from surrounding areas of the Reserve. Then, some tamarins from neighboring forest fragments could already be infected with Tc II and, after their blood-feeding the triatomines have flew to the neighboring habitat [40].

Several of those areas are located within a radius of 5 km that could be reached by the triatomines that have a considerable flight range [41].

Besides, a specimen of *Triatoma vitticeps* captured in one of those places was described posteriorly as infected with *T. cruzi* II, the same lineage isolated of the golden lion tamarins living in Poço das Antas Biological Reserve.

There are several records about the *T. vitticeps* with high percentages of natural infection by *T. cruzi* in the Atlantic rainforest, southeast Brazil.

In addition, it was capable to maintain long term infection by the same lineage of the parasite, and have been frequently described in natural infection, with corroborates with the possibility of vector dispersion [42].

It is likely, that because the tamarins of the Poço das Antas Biological Reserve were living isolated as referred by the authors, that population would be naïve to Tc II lineage of *T. cruzi*, consequently they presented the infection patterns correspondent to recently infected animals, confirmed by some cases of seroconversions recorded.

Following the studies with *T. cruzi infections*, Monteiro *et al.* [43] presented clinical, biochemical, and electrocardiographic aspects of *T. cruzi* infection in free-ranging golden lion tamarins (*L. rosalia*).

They concluded that given the similarities of human disease and *T. cruzi* infection in tamarins, mortality rates of near 13% could expect because associated cardiac problems.

An overall death rate from 4% to 7% for tamarins from the Poço das Antas, was estimated based on the prevalence of *T. cruzi* that varied from 32% to 52%.

The death of sick animals was suggested as also increasing by indirect factors such as predation, considering that it has been responsible for a reduction of the size tamarin population by 40% in the area.

In the same year, the above-mentioned authors [44] examined the correlation of *Trypanosoma cruzi* and intestinal helminths infections in wild golden lion tamarins *Leontopithecus rosalia* and golden-headed lion tamarins *L. chrysomelas* (Callitrichidae, L., 1766).

They observed high percentages of *Trypanosoma cruzi* seroprevalence ranging from 13% to 47%. In addition, it was suggested that the increase in helminth

prevalence associated with *T. cruzi* infection was apparently related to the type of helminth pathogenic action.

In addition, the increased helminth prevalence associated with *T. cruzi* infection, was suggested as apparently related to a type of helminth pathogenic action.

It showed how one determined species of parasite could influence on the behavior of a different one, affecting its pathogenicity.

Lisboa *et al.* [45] presented the results from an 11-year follow-up investigating the infection with *Trypanosoma cruzi* in lion tamarins (*Leontopithecus* spp).

It was concluded, that the infectivity competence of the golden lion tamarin fluctuates presenting peak every other year. Furthermore, both golden and golden-headed lion tamarins were able to maintain long-lasting infections by different sub-populations of *Trypanosoma cruzi*.

Those above information suggest that *Trypanosoma cruzi* probably could already exist before in these areas utilized for reintroduction of the animals.

Finally, Kerr *et al.* [38] through lineage-specific serology, verified that Atlantic forest lion tamarins, *Leontopithecus chrysomelas* and *Leontopithecus rosalia*, were reservoir hosts of *Trypanosoma cruzi* II (TcII), a lineage that has been commonly associated with severe Chagas disease in South America.

Actually, those observations also show how complex can be the biological interactions involving parasites, vectors and hosts, mainly with those parasites species with diverse vectors and hosts like the *T. cruzi*.

In fact, *Trypanosoma cruzi*, besides of being a causative agent of Chagas disease, which is still a serious health problem without a vaccine, and drug treatment, produces several side effects. It is a very common parasite infecting a great quantity of different sylvatic mammal species in many countries from Central to South America but even so, in a relatively small area inside of a forest, the behavior of the parasite can vary drastically affecting the hosts in different ways.

Here one important aspect must be highlighted concerning rescuing of sylvatic animals, this have to be considered firstly a potential public health issue.

So, all the professionals that will work in contact with the animals, or biological samples they must be properly trained and utilize the required personal protection equipment in agreement with biosecurity standards.

## 3. Conclusions

In conclusion, all the above information shows how indispensable is the searching of parasite infection among rescued sylvatic animals, before releasing it back into the wild.

Another important point mentioned in the literature above was the geo referencing of the places where the animals were found. It would be a very useful tool for digitally mapping the points where sylvatic cycles of various infectious microorganisms occur, showing the potential risks of infection from each re-

gion. It would also determine possible dangerous parasite interactions, even considering groups of forest fragments. It also would determine possible hazardous parasite interactions.

Actually all those records systematically assembled also could be very helpful on the choice of probable places for a species relocation.

It also showed the necessity of the creation of one easily reached system integrating a multidisciplinary databank where one professional could utilize information of each specific biome. The information could include scientific records about ecology and ethology of a great number of species, besides all the knowledge related to infectious diseases and the biological cycles of each autochthonous etiological agent, containing natural hosts and sylvatic vectors.

The importance of returning sylvatic animals to the wild is undeniable, nevertheless to make it reasonably, as already stated it is necessary deploying animal health bases exclusively committed with wildlife protection but also combined with a public health conscience.

Those centers would minimize the likelihood of disease spreading related to reintroduction of sylvatic animals and the transmission of these infectious agents to the resident fauna but also mitigate effects of potential emerging and re-emerging zoonosis.

In fact, it will also provide important information for preventing emerging zoonosis.

The formation of a net of multidisciplinary teams of specialists integrating the information is fundamental, besides of helping the assessment for each specific situation, it could enable the collecting of biological samples from those animals for a great number of research fields such as DNA sequencing, biology of parasite, taxonomy, production of medicines and vaccines, among others.

Moreover, the formation of a Banc constituted by Tissue samples from sylvatic specimens could signify a valuable reserve for the genetic inheritance of many determined ecosystems.

It could also represent an important opportunity to study the role of various wild animals as hosts of infectious agents, including vulnerable and endangered species.

In reality, sometimes it is very difficult for the detection of parasites in animals with subpatent infections or symptomless, often requiring specific tests. On the other hand, multiple infections among sylvatic animal hosts involving different parasites species or even different strains from the same species may be very common [46] [47].

Essentially, every single biome presents an intricate pattern of niches sustaining an immense diversity of species, and each individual presenting an even more significant range of parasites.

Among the several points related to wildlife, translocations and the risk of disease transmission above remarked. One of that currently still represents a gap is the lack of information about sylvatic hosts of a great number of infectious agents. In function of that, we presented below several tables showing records of

wild mammal infections with several parasitic protozoan.

The order of the mammal species showed in the tables followed the molecular studies based on DNA analysis proposed by Tarver *et al.* [2].

In spite of the incongruences on the literature in relation to molecular phylogenetic analyses, some studies of DNA sequencing have supported that approach but even so, the criterion utilized was just for a didactic purpose for assembling the data.

Indeed all the animals were identified at least at genus level.

**Monotremata**

Monotremes belong the subclass Prototheria and are one of the three living groups of mammals, together with marsupials (Metatheria) and placentals (Eutheria).

Characteristically they lay eggs instead of giving birth to pups, but like all other mammals, nurse their young with milk (**Figure 1**, **Table 6**).

**Marsupialia**

Marsupials are any members of the mammalian infraclass Marsupialia (from Latin *marsupium* pouch). All extant marsupials are endemic to Australasia and the Americas.

**Figure 1.** *Tachyglossus aculeatus.*

**Table 6.** Records of infections of Monotremata with parasitic protozoa, including the host and parasite species as well as the place and reference numbers.

| **Monotremata** | | | |
|---|---|---|---|
| **Host** | **Disease agent** | **Place** | **Ref. number** |
| Platypus *Ornithorhynchus anatinus* | *Theileria ornithorhynchi* | Australia | [48] [49] |
| | *Trypanosoma binneyi* | Australia | [50] |
| Short-beaked echidna *Tachyglossus aculeatus* | *Theileria tachyglossi* | Australia | [48] |
| | Coccidia | Australia | [51] |
| | *Hepatozoon tachyglossi* | Australia | [52] |
| | *Eimeria echidnae* | Australia | [53] |

A distinctive characteristic common to those animals is that the offspring are born while they are still in the embryonic stage, and they crawl to a pouch or abdominal skin folds for completing their development (Figure 2, Table 7).

Figure 2. *Marmosops incanus*.

Table 7. Records of infections of marsupials with parasitic protozoa, including the host and parasite species as well as the place and reference numbers.

| **Marsupialia** | | | |
|---|---|---|---|
| **Australian Marsupials** | | | |
| **Host** | **Disease agent** | **Place** | **Ref. number** |
| Southern brown bandicoot *Isoodon obesulus* | *Theileria perameles* | Australia | [54] |
| | *Trypanosoma vegrandis* | Australia | [55] |
| | *Trypanosoma copemani* | Australia | [55] |
| Northern brown bandicoot *Isoodon macrourus* | *Trypanosoma thylacis* | Australia | [55] |
| Long-nosed bandicoot *Perameles nasuta* | *Theileria perameles* | Australia | [54] |
| Long-nosed potoroo *Potorous tridactylus* | *Theileria perameles* | Australia | [54] |
| Gilbert's Potoroo *Potorous gilbertii* | *Theileria gilberti* | Australia | [56] |
| | *Trypanosoma copemani* | Australia | [55] |
| Woylie or brush-tailed bettong *Bettongia penicillata* | *Theileria penicillata* | Australia | [57] |
| | *Trypanosoma copemani* | Australia | [55] |
| | *Trypanosoma vegrandis* | Australia | [55] |
| | *Trypanosoma sp H25* | Australia | [55] |
| Quokka *Setonix brachyurus* | *Theileria brachyuri* | Australia | [57] |
| | *Trypanosoma copemani* | Australia | [55] |
| Eastern Grey Kangaroos *Macropus giganteus* | *Babesia macropus* | Australia | [58] |
| | *Eimeria hestermani* | Australia | [59] |

**Continued**

| | | | |
|---|---|---|---|
| | *Eimeria toganmainensis* | Australia | [59] |
| | *Eimeria wilcanniensis* | Australia | [59] |
| | *Eimeria macropodis* | Australia | [59] |
| | *Eimeria marsupialium* | Australia | [59] |
| | *Eimeria gungahlinensis* | Australia | [59] |
| | *Eimeria yathongensis* | Australia | [59] |
| | *Trypanosoma sp. H25* | Australia | [55] |
| Red Kangaroo *Macropus rufus* | *Toxoplasma gondii* | Australia | [60] |
| | *Eimeria toganmainensis* | Australia | [59] |
| | *Eimeria wilcanniensis* | Australia | [59] |
| | *Eimeria macropodis* | Australia | [59] |
| | *Leishmania spp* | Australia | [61] |
| Western grey kangaroo *Macropus fuliginosus* | *Toxoplasma gondii* | Australia | [60] |
| | *Eimeria toganmainensis* | Australia | [59] |
| | *Eimeria hestermani* | Australia | [59] |
| | *Theileria fuliginosa* | Australia | [57] |
| | *Eimeria wilcanniensis* | Australia | [59] |
| | *Eimeria macropodis* | Australia | [59] |
| | *Eimeria marsupialium* | Australia | [59] |
| | *Eimeria gungahlinensis* | Australia | [59] |
| | *Eimeria yathongensis* | Australia | [59] |
| | *Trypanosoma vegrandis* | Australia | [55] |
| Common wallaroo *Macropus robustus* | *Toxoplasma gondii* | Australia | [60] |
| | *Eimeria wilcanniensis* | Australia | [59] |
| | *Leishmania spp* | Australia | [61] |
| Red-necked wallaby *Macropus rufogriseus* | *Eimeria hestermani* | Australia | [59] |
| | *Eimeria toganmainensis* | Australia | [59] |
| | *Eimeria macropodis* | Australia | [59] |
| | *Eimeria flindersi* | Australia | [59] |
| | *Eimeria prionotemni* | Australia | [59] |
| | *Eimeria desmaresti* | Australia | [59] |
| Black-striped wallaby *Macropus dorsalis* | *Eimeria hestermani* | Australia | [59] |
| | *Eimeria macropodis* | Australia | [59] |
| | *Eimeria prionotemni* | Australia | [59] |
| Tammar wallaby *Macropus eugenii* | *Eimeria hestermani* | Australia | [59] |
| | *Eimeria toganmainensis* | Australia | [59] |
| | *Eimeria macropodis* | Australia | [59] |

**Continued**

| | | | |
|---|---|---|---|
| | *Eimeria flindersi* | Australia | [59] |
| | *Eimeria prionotemni* | Australia | [59] |
| | *Trypanosoma vegrandis* | Australia | [55] |
| Western brush wallaby *Macropus irma* | *Eimeria macropodis* | Australia | [59] |
| Whip-tailed wallaby *Macropus parryi* | *Eimeria macropodis* | Australia | [59] |
| | *Eimeria mykytowyczi* | Australia | [59] |
| | *Eimeria prionotemni* | Australia | [59] |
| | *Eimeria parryi*, | Australia | [59] |
| Parma wallaby *Macropus parma* | *Eimeria macropodis* | Australia | [59] |
| | *Eimeria parma* | Australia | [59] |
| Antilopine wallaroo *Macropus antilopinus* | *Eimeria flindersi* | Australia | [59] |
| | *Eimeria mykytowyczi* | Australia | [59] |
| Agile wallaby *Macropus agilis* | *Eimeria prionotemni* | Australia | [59] |
| | *Eimeria mykytowyczi* | Australia | [59] |
| | *Leishmania spp* | Australia | [61] |
| | *Trypanosoma evansi* | Australia | [55] |
| black wallaroo *Macropus bernardus* | *Leishmania spp* | Australia | [61] |
| Chuditch Western quoll *Dasyurus geoffroii* | *Trypanosoma vegrandis* | Australia | [50] |
| | *Trypanosoma vegrandis* | Australia | [55] |
| Tiger quoll *Dasyurus maculatus* | *Trypanosoma copemani* | Australia | [50] |
| | *Trypanosoma copemani* | Australia | [55] |
| Northern Quoll *Dasyurus hallucatus* | *Babesia thylacis* | Australia | [62] |
| Northern brownbandicoot *Isoodon macrourus* | *Trypanosoma thylacis* | Australia | [50] |
| *Pearson Island rock-wallaby Petrogale lateralis pearsoni* | *Eimeria petrogale* | Australia | [63] |
| | *Eimeria sharmani* | Australia | [63] |
| | *Eimeria godmani* | Australia | [63] |
| | *Eimeria inornata* | Australia | [63] |
| *Quokka Setonix brachyurus* | *Eimeria setonocis* | Australia | [64] |
| | *Eimeria volckertzooni* | Australia | [64] |
| | *Eimeria quokka* | Australia | [64] |
| *Tasmanian pademelon Thylogale billardierii* | *Eimeria thylogale* | Australia | [64] |
| | *Eimeria obendorfi* | Australia | [64] |
| | *Eimeria ringaroomaensis* | Australia | [64] |
| *Swamp wallaby Wallabia bicolor* | *Eimeria wallabiae* | Australia | [64] |
| | *Eimeria bicolor* | Australia | [64] |

**Continued**

| | | | |
|---|---|---|---|
| *Hare-wallabies*<br>*Lagorchestes conspicillatus* | *Eimeria lagorchestis* | Australia | [64] |
| *Tree-kangaroo*<br>*Dendrolagus lumholtzi* | *Eimeria lumholtzi* | Australia | [64] |
| | *Eimeria dendrolagi* | Australia | [64] |
| Kultarr-"Jerboa-marsupial"<br>*Antechinomys spenceri* | *Toxoplasma gondii* | Australia | [65] |
| *Antechinus spp* | *Toxoplasma gondii* | Australia | [65] |
| Crest-tailed mulgara<br>*Dasycercus cristicauda* | *Toxoplasma gondii* | Australia | [65] |
| Kowari *Dasyuroides byrnei* | *Toxoplasma gondii* | Australia | [65] |
| Fat-tailed dunnart<br>*Sminthopsis crassicaudata* | *Toxoplasma gondii* | Australia | [65] |
| White-footed dunnart<br>*Sminthopsis leucopus* | *Toxoplasma gondii* | Australia | [65] |
| Common wombat<br>*Vombatus ursinus* | *Trypanosoma copemani* | Australia | [55] |
| Koala *Phascolarctos cinereus* | *Trypanosoma irwini* | Australia | [55] |
| | *Trypanosoma copemani* | Australia | [55] |
| | *Trypanosoma gillett* | Australia | [55] |
| | *Trypanosoma vegrandis* | Australia | [66] |
| | *Trypanosoma gilletti* | Australia | [66] |
| **New World Marsupials** | | | |
| *Didelphis spp* | *Sarcocystis spp* | Brazil | [67] |
| Black eared opossum<br>*Didelphis aurita* | *Trypanosoma cruzi* | Brazil | [68] |
| | *Trypanosoma cruzi*<br>**(in scent glands)* | Brazil | [68] |
| | *Leishmania forattinii* | Brazil | [61] |
| | *Leishmania infantum* | Brazil | [61] |
| | *Leishmania amazonensis* | Brazil | [61] |
| | *Trypanosoma freitasi* | Brazil | [69] |
| Common opossum<br>*Didelphis marsupialis* | *Trypanosoma cruzi* | Brazil | [68] |
| | *Leishmania amazonensis* | Brazil | [61] |
| | *Leishmania guyanensis* | Brazil | [61] |
| | *Leishmania mexicana* | Brazil | [61] |
| | *Leishmania infantum* | Colombia | [61] |
| | *Leishmania infantum* | Venezuela | [61] |
| | *Leishmania braziliensis* | Colombia | [61] |
| Common opossum | *Leishmania braziliensis* | Venezuela | [61] |
| | *Leishmania* ( *Viannia* ) *spp* | Colombia | [61] |
| | *Leishmania mexicana* | Honduras | [61] |
| | *Trypanosoma rangeli* | Brazil | [70] |
| White-eared opossum<br>*Didelphis albiventris* | *Trypanosoma cruzi* | Brazil | [68] |

**Continued**

| | | | |
|---|---|---|---|
| | *Trypanosoma cruzi* | Paraguay | [71] |
| | *Leishmania infantum* | Brazil | [61] |
| | *Leishmania braziliensis* | Brazil | [61] |
| | *Leishmania amazonensis* | Brazil | [61] |
| | *Leishmania guyanensis* | Brazil | [61] |
| Andean white-eared opossum *Didelphis pernigra* | *Leishmania peruviana* | Peru | [61] |
| Northern red-sided opossum *Monodelphis brevicaudata* | *Trypanosoma cruzi* | Brazil | [68] |
| Grey *short-tailed opossum* *Monodelphis domestica* | *Trypanosoma cruzi* | Paraguay | [71] |
| | *Leishmania* (*Viannia*) *spp* | Brazil | [61] |
| Southeastern four-eyed opossum *Philander frenatus* | *Trypanosoma cruzi* | Brazil | [68] |
| Gray four-eyed opossum *Philander opossum* | *Trypanosoma cruzi* | Brazil | [68] |
| | *Leishmania amazonensis* | Brazil | [61] |
| Bare-tailed woolly opossum *Caluromys philander* | *Trypanosoma cruzi* | Brazil | [68] |
| | *Leishmania spp* | Trinidad | [61] |
| | *Leishmania braziliensis* | Trinidad | [61] |
| | *Leishmania garnhami* | Trinidad | [61]] |
| Brown four-eyed opossum *Metachirus nudicaudatus* | *Trypanosoma cruzi* | Brazil | [68] |
| | *Leishmania amazonensis* | Brazil | [61] |
| Murine mouse opossum *Marmosa murina* | *Leishmania amazonensis* | Brazil | [61] |
| | *Leishmania braziliensis* | Brazil | [61] |
| Long-furred woolly Mouse Opossum *Marmosa demerarae* | *Leishmania amazonensis* | Brazil | [61] |
| | *Leishmania braziliensis* | Colombia | [61] |
| Robinson's mouse opossum *Marmosa robinsoni* | *Leishmania spp* | Trinidad | [61] |
| | *Leishmania mexicana* | Panamá | [61] |
| Mexican mouse opossum *Marmosa mexicana* | *Leishmania mexicana* | Mexico | [61] |
| Grey Slender Opossum *Marmosops incanus* | *Leishmania guyanensis* | Brazil | [61] |
| | *Leishmania braziliensis* | | [61] |
| Dusky slender opossum (*Marmosops fuscatus*) | *Leishmania spp* | Colombia | [61] |
| The agile gracile opossum *Gracilinanus agilis* | *Leishmania spp* | Brazil | [61] |
| *Elegant fat-tailed mouse opossum* *Thylamys elegans* | *Sarcocystis* | Chile | [72] |

### Afrotheria

Afrotheria is a clade of mammals, of which include groups that are currently living either in Africa or of African origin.

Most of afrotheres present slight or no morphological likeness, and their relationships have only become known not long in function of genetics and molecular studies.

Among the groups of Afrotheria, those which currently live out of Africa, include animals of the Family Trichechidae represented by two species in the order Sirenia, the Amazonian manatee (*Trichechus inunguis*) and the West Indian manatee (*Trichechus manatus*) (Figure 3, Table 8).

### Xenarthra

Xenarthra is a group of placental mammals from the New World represented by anteaters, tree sloths and armadillos.

It currently has 13 genera with 30 species, mostly native to South and Central America, except the nine-band armadillo (Dasypus novencinctus) that occurs in North America. The radiation of xenarthrans occurred during the Tertiary Period when South America was an island continent (Figure 4, Table 9).

Figure 3. *Procavia capensis*.

Table 8. Records of infections of afrotherian with parasitic protozoa, including the host and parasite species as well as the place and reference numbers.

| Afrotheria | | | |
|---|---|---|---|
| **Host** | **Disease agent** | **Place** | **Ref. number** |
| Rock Hyraxes *Procavia capensis* | *Leishmania tropica* | Israel | [73] |
| Bush hyrax *Heterohyrax brucei* | *Leishmania aethiopica* | Ethiopia | [74] |
| | *Leishmania aethiopica* | Kenya | [74] |
| Southern tree hyrax *Dendrohyrax arboreus* | *Leishmania aethiopica* | Africa | [74] |
| Amazonian manatee *Trichechus inunguis* | *Cryptosporidium spp.* | Brazil | [75] |
| | *Giardia sp.* | Brazil | [75] |

**Figure 4.** *Dasypus novemcictus*.

**Table 9.** Records of infections of Xenarthra with parasitic protozoa, including the host and parasite species as well as the place and reference numbers.

| **Xenarthra** | | | |
|---|---|---|---|
| **Host** | **Disease agent** | **Place** | **Ref. number** |
| Nine-banded armadillo *Dasypus novemcinctus* | *Leishmania spp* | Brazil | [76] |
| | *Trypanosoma cruzi* | Paraguay | [71]] |
| | *Trypanosoma cruzi* | Bolivia | [77] |
| | *Trypanosoma cruzi* | Colombia | [77] |
| | *Leishmania naiffi* | Brazil | [78] |
| Six-banded armadillo *Euphractus sexcinctus* | *Trypanosoma cruzi* | Paraguay | [71] |
| Hairy armadillo *Chaetophractus spp.* | *Trypanosoma cruzi* | Paraguay | [71] |
| Two-toed sloth *Choloepus didactylus* | *Trypanosoma preguici* | Brazil | [71] |
| | *Trypanosoma leeuwenhoeki* | Panama | [71] |
| | *Endotrypanum schaudinni* | Brazil | [79] |
| | *Leishmania shawi* | NS | [74] |
| | *Leishmania guyanensis* | NS | [74] |
| Hoffmann's two-toed sloth *Choloepus hoffmanni* | *Leishmania panamensis* | NS | [74] |
| | *Leishmania colombiensis* | NS | [74] |
| Maned sloth *Bradypus torquatus* | *Trypanosoma cruzi* | Brazil | [80] |
| Brown-throated sloth *Bradypus variegatus* | *Leishmania shawi* | NS | [74] |
| Collared anteater *Tamandua tetradactyla* | *Trypanosoma legeri* | Brazil | [71] |
| | *Leishmania amazonensis* | Brazil | [74] |

### Euarchonta

The Euarchonta have been proposed as encompassing three extant orders: the Scandentia or treeshrews, the Dermoptera or colugos, and the Primates (Figure 5, Table 10).

Figure 5. *Leontopithecus rosalia*.

Table 10. Records of infections of Euarchonta with parasitic protozoa, including the host and parasite species as well as the place and reference numbers.

| Euarchonta | | | |
|---|---|---|---|
| **Host** | **Disease agent** | **Place** | **Ref. number** |
| Common squirrel monkey *Saimiri sciureus* | *Trypanosoma rangeli* | Brazil | [70] |
| | *Trypanosoma saimiri* | Brazil | [70] |
| | *Toxoplasma gondii* | London | [81] |
| Pygmy marmoset *Cebuella pygmaea* | *Trypanosoma rangeli* | Brazil | [70] |
| White-lipped tamarin *Saguinus labiatus* | *Trypanosoma rangeli* | Brazil | [70] |
| Brown-mantled tamarin *Saguinus fuscicollis* | *Trypanosoma rangeli* | Brazil | [70] |
| Red-handed tamarin *Saguinus midas* | *Trypanosoma cruzi* | Brazil | [80] |
| Pied tamarin *Saguinus bicolor* | *Trypanosoma cruzi* | Brazil | [80] |
| **Ochraceus bare-face tamarin *Saguinus ochraceus*** | *Trypanosoma cruzi* | Brazil | [80] |
| Red-bellied titi monkey *Callicebus maloch cripeus* | *Trypanosoma rangeli* | Brazil | [70] |
| Red-bellied titi monkey *Callicebus maloch* | *Trypanosoma cruzi* | Brazil | [80] |
| Purus red howler *Alouatta p.* ***stramineus*** | *Trypanosoma rangeli* | Brazil | [70] |

**Continued**

| | | | |
|---|---|---|---|
| Black titi<br>*Callicebus lugens* | *Trypanosoma rangeli* | Brazil | [70] |
| Gracile capuchin monkeys<br>*Cebus spp* | *Leishmania shawi* | Brazil | [79] |
| White-fronted capuchin<br>*Cebus albifrons* | *Trypanosoma cruzi* | Brazil | [80] |
| Tufted capuchin<br>*Cebus apella* | *Leishmania shawi* | NS | [74] |
| Golden-headed lion tamarin<br>*Leontopithecus chrysomelas* | *Trypanosoma cruzi* | Brazil | [38] |
| Golden lion tamarin<br>*Leontopithecus rosalia* | *Trypanosoma cruzi* | Brazil | [38] |
| Black lion tamarin<br>*Leontopithecus chrysopygus* | *Trypanosoma cruzi* | Brazil | [80] |
| Black bearded saki<br>*Chiropotes satanas* | *Leishmania shawi* | NS | [74] |
| Black-striped capuchin<br>*Sapajus libidinosus* | *Trypanosoma cruzi* | Brazil | [38] |
| Red-handed howler<br>*Alouatta belzebul* | *Trypanosoma cruzi* | Brazil | [38] |
| Night monkeys<br>*Aotus sp.* | *Trypanosoma cruzi* | Bolivia | [77] |
| Black-headed night monkey<br>*Aotus nigriceps* | *Trypanosoma cruzi* | Brazil | [80] |
| Black-tufted marmoset<br>*Callithrix penicillata* | *Trypanosoma minasense* | Brazil | [82] |
| Gold-and-white marmoset<br>*Callithrix chrysoleuca* | *Trypanosoma cruzi* | Brazil | [80] |
| Bornean orangutan<br>*Pongo pygmaeus* | *Plasmodium pitheci* | Malaysia | [83] |
| | *Plasmodium silvaticum* | Malaysia | [83] |
| | *Leishmania infantum* | Spain | [84] |
| | *Entamoeba histolytica* | Indonesia | [85] |
| | *Entamoeba coli* | Indonesia | [85] |
| | *Entamoeba hartmanni* | Indonesia | [85] |
| | *Endolimax nana* | Indonesia | [85] |
| | *Iodamoeba buetschlii* | Indonesia | [85] |
| | *Blastocystis spp* | Indonesia | [85] |
| | *Balantidium spp* | Indonesia | [85] |
| | *Giardia spp* | Indonesia | [85] |
| Blue monkey<br>*Cercopithecus mitis* | *Entamoeba histolytica* | Africa | [85] |
| | *Entamoeba coli* | Africa | [85] |

**Continued**

| | | | |
|---|---|---|---|
| | *Balantidium spp* | Africa | [85] |
| Grivet *Cercopithecus aethiops* | *Entamoeba histolytica* | Africa | [85] |
| | *Entamoeba coli* | Africa | [85] |
| | *Balantidium spp* | Africa | [85] |
| | *Leishmania major* | Africa | [74] |
| Mantled guereza *Colobus guereza* | *Entamoeba histolytica* | Uganda | [85] |
| | *Entamoeba coli* | Uganda | [85] |
| Angola colobus *Colobus angolensis* | *Entamoeba histolytica* | Uganda | [85] |
| | *Entamoeba coli* | Uganda | [85] |
| Ugandan red colobus *Piliocolobus tephrosceles* | *Entamoebahistolytica* | Uganda | [85] |
| | *Entamoeba coli* | Uganda | [85] |

**Glires**

Glires is a clade comprised by rodents and lagomorphs (rabbits, hares, and pikas) forming a monophyletic group. It is a very diverse group with a world-wide distribution (Figure 6, Table 11).

**Eulipotyphla**

Eulipotyphla was suggested by molecular methods of phylogenetic reconstruction and includes the hedgehogs and gymnures, solenodons, the desmans, moles, and shrew-like moles and true shrews (Figure 7, Table 12).

**Chiroptera**

The chiropterans group is composed by the bats, they present the forelegs adapted to wings being the only mammals naturally able of flying.

After the rodents, they are the biggest mammals order, consisting of about 20% of all known species (Figure 8, Table 13).

**Cetartiodactyla**

Cetartiodactyla is the taxon that includes all even hoofed mammals including deer, camels, pigs and others. The cetaceans are also included, containing more than 450 terrestrial species, three semiaquatic, as well as close eighty aquatic representatives (Figure 9, Table 14).

**Perissodactyla**

The Perissodactyla are hoofed animals known commonly as odd-toed ungulates, it is composed of herbivorous terrestrial mammals, which the number of toes has been reduced from the ancestral with five to one in horses, three in rhinoceroses, and in the tapirs, four on the front feet and three on the hind feet.

They have been classified into three extant families the Equidae and Tapiridae comprised of one genus with respectively nine and four species, and the Rhinocerotidae with four genera and five species (Figure 10, Table 15).

**Figure 6.** *Eliomys quercinus.*

**Figure 7.** *Sorex araneus.*

**Figure 8.** *Desmodus rotundus.*

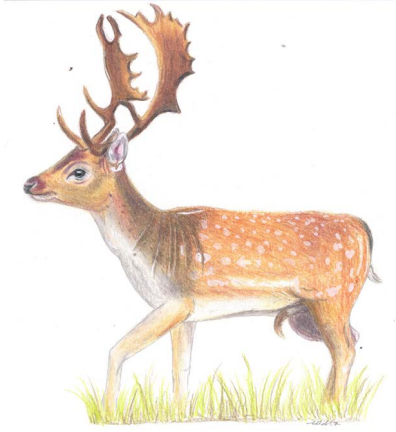

**Figure 9.** *Dama dama.*

**Figure 10.** *Ceratotherium simum*.

**Table 11.** Records of infections of Glires with parasitic protozoa, including the host and parasite species as well as the place and reference numbers.

| Glires | | | |
|---|---|---|---|
| **Host** | **Disease agent** | **Place** | **Ref. number** |
| Drab Atlantic tree-rat *Phyllomys dasythrix* | *Trypanosoma rangeli* | Brazil | [70] |
| South American water rat *Nectomys squamipes* | *Trypanosoma cruzi* | Brazil | [80] |
| | *Leishmania infantum* | Brazil | [86] |
| Common punaré *Thrichomys apereoides* | *Leishmania infantum* | Brazil | [86] |
| Garden dormouse *Eliomys quercinus* | *Trypanosoma blanchardi* | France | [70] |
| Sumichrast's vesper rat *Nyctomys sumichrasti* | *Leishmania mexicana* | NS | [74] |
| Large-headed rice rat *Hylaeamys megacephalus* *referred as *Oryzomys capito* | *Leishmania amazonensis* | NS | [74] |
| Great gerbil *Rhombomys opimus* | *Leishmania major* | Iran | [87] |
| | *Leishmania major* | Central Asia | [74] |
| | *Leishmania turanica* | Iran | [87] |
| | *Leishmania gerbilli* | Mongolia | [74] |
| | *Leishmania gerbilli* | China | [74] |
| Greater Egyptian gerbil *Gerbillus pyramidum* | *Leishmania major* | Africa | [74] |
| Indian gerbil *Tatera indica* | *Leishmania major* | Iran | [87] |
| *Tatera gambiana* | *Leishmania spp* | Nigeria | [88] |
| Emin's gerbil *Taterillus emini* | *Leishmania major* | Africa | [74] |
| Fringe-tailed gerbil *Gerbilliscus robustus* | *Leishmania major* | Africa | [74] |

**Continued**

| | | | |
|---|---|---|---|
| Indian desert gerbil *Meriones hurrianae* | *Leishmania major* | Iran | [87] |
| | *Leishmania major* | India | [74] |
| Libyan jird *Meriones libycus* | *Leishmania major* | Iran | [87] |
| | *Leishmania major* | Central Asia | [74] |
| Shaw's jird *Meriones shawi* | *Leishmania major* | Morocco | [74] |
| Sundevall's jird *Meriones crassus* | *Leishmania major* | NS | [74] |
| Desmarest's spiny pocket mouse *Heteromys desmarestianus* | *Leishmania mexicana* | NS | [74] |
| | *Leishmania panamensis* | NS | [74] |
| Short-tailed bandicoot rat *Nesokia indica* | *Leishmania major* | Iranian Khuzestan | [74] |
| Fat sand rat *Psammomys obesus* | *Leishmania major* | Saudi Arabia | [74] |
| Unstriped grass mice *Arvicanthis spp* | *Leishmania major* | Africa | [74] |
| Multimammate mouse *Mastomys spp* | *Leishmania major* | Africa | [74] |
| Natal multimammate mouse *Mastomys natalensis* | *Leishmania major* | Nigeria | [88] |
| Guinea multimammate mouse *Mastomys erythroleucus* | *Leishmania major* | Africa | [74] |
| Fat sand rat *Psammomys obesus* | *Leishmania major* | Libya | [74] |
| | *Leishmania major* | Tunisia | [74] |
| Bank vole *Myodes glareolus* | *Trypanosoma evotomys* | Hungary | [89] |
| | *Hepatozoon erhardovae* | Hungary | [89] |
| Northern short-tailed shrew *Blarina brevicauda* | *Eimeria brevicauda* | USA | [90] |
| | *Isospora brevicauda* | USA | [90] |
| Wood mouse *Apodemus sylvaticus* | *Cryptosporidium parvum* | UK | [91] |
| | *Trypanosoma grosi* | Hungary | [89] |
| | *Hepatozoon sylvatici* | Hungary | [89] |
| Yellow-necked mouse *Apodemus flavicollis* | *Cryptosporidium parvum* | Poland | [89] |
| | *Trypanosoma grosi* | Hungary | [89] |
| | *Hepatozoon sylvatici* | Hungary | [89] |
| Gambian pouched rat *Cricetomys gambianus* | *Leishmania aethiopica* | Africa | [74] |

**Continued**

| | | | |
|---|---|---|---|
| Fat sand rat<br>*Psammomys obesus* | *Leishmania major* | Algeria | [74] |
| Kaiser's rock rat<br>*Aethomys kaiseri* | *Leishmania major* | Africa | [74] |
| European hamster<br>*Cricetus cricetus* | *Trypanosoma rabinowitschae* | France | [70] |
| Short-tailed vole<br>*Microtus agrestis* | *Trypanosoma microti* | England | [70] |
| Bank vole<br>*Myodes glareolus* *referred as *Clethrionomys glareolus* | *Cryptosporidium parvum* | Finland | [91] |
| | *Cryptosporidium parvum* | Poland | [91] |
| | *Cryptosporidium parvum* | Finland | [91] |
| | *Cryptosporidium parvum* | UK | [91] |
| Prehensile-tailed porcupines<br>*Coendou spp* | *Leishmania deanei* | Brazil | [79] |
| | *Leishmania panamensis* | Panama | [74] |
| | *Leishmania hertigi* | Panama | [79] |
| Southern Plains woodrat<br>*Neotoma micropus* | *Leishmania mexicana* | USA | [74] |
| Desmarest's spiny pocket mouse<br>*Heteromys desmarestianus* | *Leishmania mexicana* | Belize | [74] |
| Big-eared climbing rat<br>*Ototylomys phyllotis* | *Leishmania mexicana* | Belize | [74] |
| Brazilian porcupine<br>*Coendou prehensilis* | *Leishmania infantum* | Bolivia | [86] |
| Guinea pigs<br>*Cavia spp* | *Leishmania enriettii* | Brazil | [79] |
| Common agouti<br>*Dasyprocta aguti* | *Trypanosoma cruzi* | Brazil | [77] |
| Brazilian marsh rat<br>*Holochilus brasiliensis* | *Trypanosoma cruzi* | Brazil | [80] |
| South American grass mice<br>Akodon *spp* | *Leishmania panamensis* | NS | [74] |
| Montane grass mouse<br>*Akodon montensis* | *Leishmania braziliensis* | Brazil | [74] |
| Hispid cotton rat<br>*Sigmodon hispidus* | *Leishmania mexicana* | NS | [74] |
| South American spiny rats<br>*Proechimys spp* | *Leishmania amazonensis* | Brazil | [74] |
| | *Leishmania amazonensis* | French Guyana | [74] |
| Colombian spiny-rat<br>*Proechimys canicollis* | *Leishmania infantum* | Colombia | [86] |
| Cuvier's spiny-rat<br>*Proechimys cuvieri* | *Leishmania guyanensis* | NS | [74] |

**Continued**

| | | | |
|---|---|---|---|
| | *Leishmania amazonensis* | NS | [74] |
| Guyenne spiny-rat *Proechimys guyannensis* | *Leishmania amazonensis* | NS | [74] |
| | *Leishmania guyanensis* | NS | [74] |
| Tome's spiny rat *Proechimys semispinosus* | *Leishmania panamensis* | NS | [74] |
| Ihering's Atlantic spiny-rat *Trinomys iheringi* | *Leishmania braziliensis* | Brazil | [74] |
| Red squirrel *Sciurus vulgaris* | *Leishmania amazonensis* | NS | [74] |
| Eastern gray squirrel *Sciurus carolinensis* | *Cryptosporidium parvum* | USA | [91] |
| Capybara *Hydrochoerus hydrochaeris* | *Trypanosoma evansi* | Brazil | [92] |
| Capybara *Hydrochoerus hydrochaeris* | *Trypanosoma evansi* | Colombia | [93] |
| Capybara *Hydrochoerus hydrochaeris* | *Trypanosoma evansi* | Peru | [94] |
| Capybara *Hydrochoerus hydrochaeris* | *Trypanosoma evansi* | Venezuela | [95] |
| Lowland paca *Cuniculus paca* | *Leishmania lainsoni* | Brazil | [74] |
| Unstriped ground squirrel *Xerus rutilus* | *Leishmania major* | Africa | [74] |
| European rabbit *Oryctolagus cuniculus* | *Cryptosporidium parvum* | Mainland Britain | [91] |

**Table 12.** Records of infections of Eulipotyphla with parasitic protozoa, including the host and parasite species as well as the place and reference numbers.

| **Eulipotyphla** | | | |
|---|---|---|---|
| **Host** | **Disease agent** | **Place** | **Ref. number** |
| European hedgehog *Erinaceus europaeus* | *Cryptosporidium parvum* | Mainland Britain | [91] |
| Common shrew *Sorex araneus* | *Cryptosporidium parvum* | Mainland Britain | [91] |
| | *Hepatozoon spp* | Hungary | [89] |
| | *Cryptosporidium parvum* | Poland | [91] |
| | *Trypanosoma spp* | England | [96] |
| Pygmy shrew Sorex minutus | *Cryptosporidium parvum* | Mainland Britain | [91] |
| | *Trypanosoma spp* | Hungary | [89] |
| Cinereous shrew *Sorex cinereus* | *Eimeria palustris* | USA | [90] |
| | *Eimeria palustris* | Canada | [90] |

**Continued**

| | | | |
|---|---|---|---|
| Maryland shrew *Sorex fontinalis* | *Eimeria palustris* | USA | [90] |
| Smoky shrew *Sorex fumeus* | *Eimeria palustris* | USA | [90] |
| | *Eimeria fumeus* | USA | [90] |
| | *Eimeria vagrantis* | USA | [90] |
| Prairie shrew *Sorex haydeni* | *Eimeria palustris* | USA | [90] |
| Southeastern shrew *Sorex longirostris* | *Eimeria palustris* | USA | [90] |
| Ornate shrew *Sorex ornatus* | *Eimeria palustris* | USA | [90] |
| Pacific shrew *Sorex pacificus* | *Eimeria palustris* | USA | [90] |
| | *Eimeria fumeus* | USA | [90] |
| American water shrew *Sorex palustris* | *Eimeria palustris* | USA | [90] |
| | *Isospora palustris* | USA | [90] |
| Inyo shrew *Sorex tenellus* | *Eimeria palustris* | USA | [90] |
| | *Eimeria inyoni* | USA | [90] |
| Trowbridge's shrew *Sorex trowbridgii* | *Eimeria palustris* | USA | [90] |
| | *Eimeria vagrantis* | USA | [90] |
| Long-clawed shrew *Sorex unguiculatus* | *Eimeria fumeus* | Japan | [90] |
| | *Isospora palustris* | Japan | [90] |
| Vagrant shrew *Sorex vagrans* | *Eimeria palustris* | USA | [90] |
| | *Eimeria vagrantis* | USA | [90] |
| | *Eimeria fumeus* | USA | [90] |
| | *Isospora palustris* | USA | [90] |

**Table 13.** Records of infections of Chiroptera with parasitic protozoa, including the host and parasite species as well as the place and reference numbers.

| **Chiroptera** | | | |
|---|---|---|---|
| **Host** | **Disease agent** | **Place** | **Ref. number** |
| Little red flying-fox *Pteropus scapulatus* | *Trypanosoma teixeirae* | Australia | [97] |
| White-lined broad-nosed bat *Platyrrhinus lineatus* | *Trypanosoma rangeli* | Brazil | [97] |
| Brazilian brown bat *Eptesicus brasiliensis* | *Trypanosoma dionisii* | Brazil | [97] |
| Free-tailed bat *Tadarida spp* | *Trypanosoma erneyi* | Mozambique | [97] |

**Continued**

| | | | |
|---|---|---|---|
| Common pipistrelle *Pipistrellus pipistrellus* | *Trypanosoma vespertilionis* | England | [97] |
| Lander's horseshoe bat *Rhinolophus landeri* | *Trypanosoma livingstonei* | Mozambique | [97] |
| Sundevall's roundleaf bat *Hipposideros caffer* | *Trypanosoma livingstonei* | Mozambique | [97] |
| Yellowish myotis *Myotis levis* | *Trypanosoma cruzi Tcbat* | Brazil | [97] |
| Seba's short-tailed bat *Carollia perspicillata* | *Trypanosoma cruzi marinkellei* | Brazil | [97] |
| | *Leishmania infantum* | Venezuela | [86] |
| Greater spear-nosed bat *Phyllostomus hastatus* | *Trypanosoma cruzi* | Peru | [98] |
| Pale spear-nosed bat *Phyllostomus discolor* | *Leishmania braziliensis* | Brazil | [99] |
| Fringe-lipped bat *Trachops cirrhosus* | *Trypanosoma cruzi* | Peru | [98] |
| White-winged vampire bat *Diaemus youngi* | *Trypanosoma cruzi* | Peru | [98] |
| Common vampire bat *Desmodus rotundus* | *Trypanosoma cruzi* | Peru | [98] |
| | *Trypanosoma cruzi marinkellei* | Brazil | [99] |
| Tailed tailless bat *Anoura caudifera* | *Leishmania braziliensis* | Brazil | [99] |
| | *Trypanosoma cruzi marinkellei* | Brazil | [99] |
| | *Trypanosoma dionisii* | Brazil | [99] |
| | *Trypanosoma wauwau* | Brazil | [99] |
| Pallas's long-tongued bat *Glossophaga soricina* | *Trypanosoma cruzi marinkellei* | Brazil | [99] |

**Table 14.** Records of infections of cetartiodactylan with parasitic protozoa, including the host and parasite species as well as the place and reference numbers.

| **Cetartiodactyla** | | | |
|---|---|---|---|
| **Host** | **Disease agent** | **Place** | **Ref. number** |
| White-tailed deer *Odocoileus virginianus* | *Toxoplasma gondii* | USA | [26] |
| | *Babesia odocoilei* | USA | [26] |
| | *Theileria cervi,* | USA | [26] |
| European roe deer *Capreolus capreolus* | *Cryptosporidium parvum* | Denmark | [91] |
| Peters's duiker *Cephalophus callipygus* | *Haemosporidian* | Africa | [100] |
| Fallow deer *Dama dama* | *Cryptosporidium parvum* | Mainland Britain | [91] |
| Reeves's muntjac *Muntiacus reevesi* | *Cryptosporidium parvum* | Mainland Britain | [91] |

**Continued**

| | | | |
|---|---|---|---|
| Black-fronted duiker *Cephalophus nigrifrons* | *Haemosporidian* | Africa | [100] |
| Blue duiker *Cephalophus monticola* | *Haemosporidian* | Africa | [100] |
| Bay duiker *Cephalophus dorsalis* | *Haemosporidian* | Africa | [100] |
| Blue whale *Balaenoptera musculus* | *Entamoeba* | Atlantic Ocean | [101] |
| Sei whale *Balaenoptera borealis* | *Giardia* | Atlantic Ocean | [101] |
| | *Entamoeba* | Atlantic Ocean | [101] |
| Fin Whale *Balaenoptera physalus* | *Giardia* | Atlantic Ocean | [101] |
| | *Entamoeba* | Atlantic Ocean | [101] |
| | *Balantidium* | Atlantic Ocean | [101] |
| killer whale *Orcinus orca* | *Toxoplasma gondii* | Brazil | [102] |
| Common bottlenose dolphin *Tursiops truncatus* | *Toxoplasma gondii* | Pacific Ocean | [103] |
| | *Toxoplasma gondii* | Brazil | [102] |
| Pygmy sperm whale *Kogia breviceps* | *Giardia* | Brazil | [75] |
| Dwarf sperm whale *Kogia sima* | *Giardia* | Brazil | [75] |
| Guiana dolphin *Sotalia guianensis* | *Giardia sp.* | Brazil | [75] |
| | *Toxoplasma gondii* | Brazil | [102] |
| | *Cryptosporidium spp.* | Brazil | [75] |
| Amazonian manatee *Trichechus inunguis* | *Cryptosporidium spp.* | Brazil | [75] |
| | *Giardia sp.* | Brazil | [75] |
| West Indian manatee *Trichechus manatus* | *Cryptosporidium spp.* | Brazil | [75] |
| | *Giardia sp.* | Brazil | [75] |

### Pholidota

The Pholidota is commonly known as pangolins or scaly anteaters. This group of mammals is composed by just seven living species, four in Africa and three in Southeast Asia.

They look like armadillos or anteaters that like them also eat insects, have long tongues, strong digging limbs, and reduced or missing teeth.

The pangolins have already been clustered with armadillos and anteaters in Edentata; however, their similarities are now considered as a result of convergent evolution (**Figure 11**, **Table 16**).

**Table 15.** Records of infections of Perissodactyla with parasitic protozoa, including the host and parasite species as well as the place and reference numbers.

| **Perissodactyla** | | | |
|---|---|---|---|
| **Host** | **Disease agent** | **Place** | **Ref. number** |
| South American tapir *Tapirus terrestris* | *Trypanosoma terrestris* | Brazil | [104] |
| | *Theileria equi* | Brazil | [105] |
| Black rhinoceros *Diceros bicornis* | *Trypanosoma congolense* | Kenia | [106] |
| | *Trypanosoma brucei* | Tanzania | [107] |
| | *Trypanosoma godfreyi* | Kenia | [106] |
| | *Trypanosoma simiae* | Kenia | [106] |
| | *Theileria spp* | Kenia | [106] |
| | *Trypanosoma vivax* | Kenia | [108] |
| White rhinoceros *Ceratotherium simum* | *Theileria spp* | Kenia | [106] |
| | *Theileria bicornis* | South Africa | [109] |
| | *Theileria equi* | South Africa | [109] |
| Sumatran rhinoceros *Dicerorhinus sumatrensis* | *Trypanosoma evansi* | Malaysia | [110] |

**Table 16.** Records of infections of Pholidota with parasitic protozoa, including the host and parasite species as well as the place and reference numbers.

| **Pholidota** | | | |
|---|---|---|---|
| **Host** | **Disease agent** | **Place** | **Ref. number** |
| Pangolin *Phataginus tricuspis* | *Haemosporidian* | Africa | [100] |
| Javan pangolin *Manis javanica* | *Eimeria tenggilingi* | Singapore | [111] |
| African Tree Pangolin *Phataginus tricuspis* | *Eimeria nkaka* | Angola | [111] |
| | *Trypanosoma brucei* | Cameroon | [112] |
| | *Trypanosoma vivax* | Cameroon | [112] |
| Indian pangolin *Manis crassicaudata* | *Toxoplasma gondii* | Belgium | [112] |
| Long-tailed pangolin *Manis tetradactyla* | *Trypanosoma brucei* | Cameroon | [112] |
| | *Trypanosoma vivax* | Cameroon | [112] |
| Temminck's ground pangolin *Manis temminckii* | *Piroplasma spp* | London | [112] |

### Carnivora

The Carnivora compound the most varied in size mammalian order, they have teeth and claws evolved for predation.

**Figure 11.** *Manis spp.*

**Figure 12.** *Leopardus pardalis.*

**Table 17.** Records of infections of Carnivora with parasitic protozoa, including the host and parasite species as well as the place and reference numbers.

| Host | Disease agent | Place | Ref. number |
|---|---|---|---|
| Bush dog *Speothos venaticus* | *Leishmania infantum* | Brazil | [89] |
| Gray fox *Urocyon cinereoargenteus* | *Toxoplasma gondii* | USA | [113] |
| Crab-eating fox *Cerdocyon thous* | *Trypanosoma cruzi* | Brazil | [114] |
| | *Leishmania infantum* | Brazil | [89] |
| Maned wolf *Chrysocyon brachyurus* | *Trypanosoma cruzi* | Brazil | [114] |
| Maned wolf | *Leishmania infantum* | Brazil | [89] |
| Hoary fox *Lycalopex vetulus* | *Trypanosoma cruzi* | Brazil | [114] |

**Continued**

| | | | |
|---|---|---|---|
| | *Leishmania infantum* | Brazil | [89] |
| Andean fox *Lycalopex culpaeus* | *Trypanosoma cruzi* | Colombia | [114] |
| | *Trypanosoma cruzi* | Argentina | [114] |
| South American gray fox *Lycalopex griseus* | *Trypanosoma cruzi* | Colombia | [114] |
| Golden jackal *Canis aureus* | *Leishmania infantum* | Algeria | [115] |
| Grey wolf *Canis lupus* | *Leishmania infantum* | Iran | [89] |
| Corsac fox *Vulpes corsac* | *Leishmania infantum* | Central Asia | [74] |
| Red fox *Vulpes vulpes* | *Leishmania infantum* | NS | [74] |
| | *Cryptosporidium parvum* | Mainland Britain | [91] |
| Fennec fox *Vulpes zerda* | *Leishmania infantum* | Africa | [74] |
| Pampas fox *Lycalopex gymnocercus* | *Trypanosoma cruzi* | Argentina | [114] |
| Raccoon dog *Nyctereutes procyonoides* | *Leishmania donovani* | NS | [74] |
| European badger *Meles meles* | *Leishmania infantum* | NS | [74] |
| | *Cryptosporidium parvum* | Mainland Britain | [91] |
| Ocelot *Leopardus pardalis* | *Trypanosoma cruzi* | Brazil | [114] |
| Cougar *Puma concolor* | *Trypanosoma cruzi* | Brazil | [114] |
| Ring-tailed coati *Nasua nasua* | *Trypanosoma cruzi* | Brazil | [114] |
| | *Trypanosoma evansi* | Brazil | [116] |
| | *Leishmania shawi* | NS | [74] |
| Iberian lynx *Lynx pardinus* | *Leishmania infantum* | Spain | [89] |
| Serval *Leptailurus serval* (*) | *Leishmania donovani* | NS | [74] |
| Egyptian mongoose *Herpestes ichneumon* | *Leishmania infantum* | Spain | [89] |
| Raccoon *Procyon lotor* | *Toxoplasma gondii* | USA | [113] |
| | *Trypanosoma cruzi* | USA | [77] |
| Crab-eating raccoon *Procyon cancrivorus* | *Trypanosoma cruzi* | Brazil | [114] |

**Continued**

| | | | |
|---|---|---|---|
| Striped skunk *Mephitis mephitis* | *Toxoplasma gondii* | USA | [113] |
| Common genet *Genetta genetta* | *Leishmania infantum* | Spain | [89] |
| | *Leishmania donovani* | NS | [74] |
| Molina's hog-nosed skunk *Conepatus chinga* | *Trypanosoma cruzi* | Argentina | [114] |
| American mink *Neovison vison* | *Toxoplasma gondii* | USA | [113] |
| Tayra *Eira barbara* | *Trypanosoma cruzi* | Brazil | [114] |
| | *Trypanosoma cruzi* | Argentina | [114] |
| Neotropical river otter *Lontra longicaudis* | *Cryptosporidium spp.* | Brazil | [75] |
| | *Giardia sp.* | Brazil | [75] |
| Giant river otter *Pteronura brasiliensis* | *Cryptosporidium spp* | Brazil | [75] |
| | *Giardia sp.* | Brazil | [75] |
| Lesser grison *Galictis cuja* | *Trypanosoma cruzi* | Argentina | [114] |
| | *Trypanosoma cruzi* | Brazil | [114] |
| Greater grison *Galictis vittata* | *Trypanosoma cruzi* | Brazil | [114] |
| Kinkajou *Potos flavus* | *Trypanosoma cruzi* | Colombia | [114] |
| | *Leishmania amazonensis* | NS | [74] |
| Kuril harbour seal *Phoca vitulina* | *Toxoplasma gondii* | Japan | [117] |
| | *Neospora caninum* | Japan | [117] |
| Spotted seal *Phoca largha* | *Toxoplasma gondii* | Japan | [117] |
| | *Neospora caninum* | Japan | [117] |
| Mediterranean monk seal *Monachus monachus* | *Leishmania infantum* | Turkey | [118] |

NS: Not specified, (*) Referred as *Felix serval*.

Generally, the term carnivore is applied to members of this group as meat-eating animals.

Although several carnivorans like in felids the diet is composed almost exclusively of meat, it may vary, bears for example are omnivorous and the giant panda is mainly herbivore. Many hunt in groups and present a social behavior and with some exceptions, they have six incisors and two narrowed canines in each jaw (**Figure 12**, **Table 17**).

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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