

Infectious diseases and extinction risk in wild mammals

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Abstract

Infectious diseases can cause significant declines in wildlife populations, with recent examples provided by pathogens infecting African apes, North Sea harbor seals, African wild dogs and Serengeti lions. In this study, we examined the characteristics of pathogens reported as causing declines or mortality in threatened mammal populations and the biological characteristics of the mammalian hosts. We used the IUCN Red List database to identify 51 mammal species classified as being threatened due to infectious diseases. Species threatened by pathogens were primarily confined to two taxonomic groups: Carnivora and Artiodactyla. Pathogens reported to threaten wild mammal hosts were predominantly categorized as generalist viruses, most of which could also infect domesticated animals. Surprisingly little published information was available on parasite occurrence and impacts for many of the most threatened host species. Collectively, these results suggest that generalist pathogens represent a serious concern for wild mammalian populations, especially for species with close evolutionary relationships to domesticated animals, but currently there is a paucity of published information about specific pathogens affecting threatened mammals.

Background

Many pathogens affecting humans, such as HIV, Ebola, and SARS are zoonotic and can be maintained in wildlife populations. Existing and emerging pathogens have also caused striking declines in wildlife, as illustrated by CDV affecting Serengeti lions, Ebola virus in chimpanzees and gorillas, plague affecting prairie dogs, and PDV outbreaks in harbor seals.



General host-parasite theory predicts that directly-transmitted diseases will not drive their host to extinction. This theoretical prediction is based on pathogens affecting a single host species with density-dependent transmission. Yet parasite-induced extinction might be possible in several other cases. First, some parasites can infect multiple host species, and high prevalence in reservoir hosts can lead to high infection rates in vulnerable species. Second, the transmission of other pathogens, such as STDs and vector-borne diseases, might not suffer from reduction in host density. Third, many threatened mammals suffer from multiple factors that could predispose them to extinction risk, with infectious diseases representing one of many contributing factors. Despite these general predictions, few studies have examined the characteristics of parasites implicated in the extinction risk of large numbers of host species.

Objectives and predictions

Wild mammals are a well-studied host clade and capture some of the most threatened species worldwide. Because of their close relationships to humans and domesticated animals, much is known about infectious diseases in wild mammals. The goal of our study was to develop a comprehensive data set of host and parasites species that have been implicated in recent mammal declines. We used these data to examine the following predictions:

- Mammals classified as being threatened by infectious diseases will be mainly from lineages that are closely related to domesticated animals
- Pathogens reported to cause harm in threatened mammals will be dominated by viruses and by generalist parasites that can infect domesticated animals as reservoir hosts
- Little information on parasite occurrence will be available for the majority of threatened mammal species

Host and parasite data

Host Threat Status. We gathered data on the threat status (extinct, critically endangered, endangered, conservation dependent, low risk, and least concern) and the threatening process for all mammals using the IUCN's 2004 Red List (www.redlist.org). We also searched for host species flagged by the IUCN as being threatened by disease.

Parasites from Threatened Mammals. We systematically searched the peer-reviewed and grey literature for pathogens and parasites that might contribute to host threat status. Each parasite was assigned a confidence score based on the quality and quantity of available information. For some host species flagged by the IUCN as being threatened by parasites, we found no evidence of disease-causing agents from wild populations. We further recorded the following information for each parasite documented as causing a population decline or having strong negative effects on mortality or fecundity: taxonomic group, host specificity, transmission mode, effect on host fitness, role in population declines, and presence in domestic animals.

Global Mammal Parasite Database. For a subset of analyses, we used a comprehensive database of the parasites and pathogens of free-living primates, carnivores and ungulates (www.mammalparasites.org). These data were derived from systematic searches of reports from the published literature. In total, parasite data were available for 362 mammal species, including 119 primates, 146 carnivores and 97 hoofed mammals, capturing 111 host species listed as being threatened by the IUCN.

Results

1. Parasite-threatened hosts were disproportionately represented in animal lineages with domesticated species

- The Artiodactyls (32%, n=92) and Carnivores (20%, n=94) were significantly over-represented, while Chiroptera (0%, n=293) and Rodentia (<1%, n=429) were under-represented in the distribution of parasite threatened hosts when compared across all threatened mammals (Fig. 1a, $\chi^2 = 231.2$, d.f. = 14, $p < 0.0001$).
- Within the carnivores, the Canids (15%) and Felids (8%) had a higher proportion of species threatened by parasites than other carnivore families (Fig. 1b, $\chi^2 = 21.6$, d.f. = 7, $p = 0.003$).
- Within the Artiodactyla, Bovids (15%) & Suids (25%) had more species threatened by parasites, but this difference was not significant (Fig. 1c, $\chi^2 = 4.0$, d.f. = 4, $p > 0.05$).

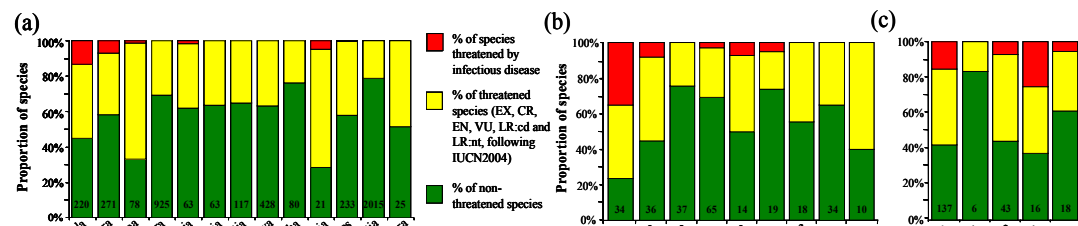


Fig 1. Distribution of (a) mammalian orders, (b) artiodactyl families, and (c) carnivore families that are not threatened (green), threatened by other factors (yellow) and threatened by parasites (red).

2. Parasites that threatened wild mammals were predominantly viruses, shared with domesticated animals, and transmitted by close contact between individuals

Parasite Taxonomy: 26 parasite species were identified as contributing to the threat status of mammals (see Table 1). Viruses (46%), bacteria (17%) and helminths (12%) were the most represented, although this pattern was different between the two host groups –Artiodactyla (Fig 2a and Carnivores (Fig 2b).

Table 1. The list of parasites characterized as threatening mammalian

PARASITE TYPE	# CARN. SPS.	# ARTIO. SPS.	# OTHER SPS.
VIRUS			
Canine Distemper Virus (CDV)	10	0	0
Canine Parvovirus	4	0	0
Feline Calicivirus (FCoV)	1	0	0
Feline Panleukopenia (Distemper)	1	0	0
Feline Leukemia Virus	0	0	0
Foot and Mouth Virus	0	7	0
Jembrana Disease Virus	0	1	0
Monk Seal Morbillivirus	1	0	0
Ovineherpes Virus 2 (SA-MCF)	0	1	0
Pseudo Rabies Virus	1	0	0
Rabies	9	2	0
Rinderpest Virus	0	7	0
BACTERIA			
<i>Bacillus anthracis</i> (Anthrax)	0	5	0
<i>Mycobacterium bovis</i> (Bovine Tuberculosis)	0	2	0
<i>Fusobacterium necrophorum</i> (Hoof rot)	0	1	0
<i>Pasteurella</i> sp. (Pasteurellosis)	0	2	0
<i>Yersinia pestis</i> (Black Plague)	0	0	1
HELMINTHS			
<i>Angiostrongylus gubernaculatus</i> (nematode)	1	0	0
<i>Dioctophyme renale</i> (Giant Kidney Worm)	1	0	0
<i>Diffilaria immitis</i> (Heartworm)	1	0	0
<i>Protostrongylus</i> sp. (Lungworm)	0	1	0
<i>Taenia hydatigena</i> (Thin-necked Bladderworm)	0	1	0
ARTHROPODS			
<i>Otodectes cynotis</i> (Ear Canker Mite)	1	0	0
<i>Psoroptes</i> sp. (Psoroptic Mange)	0	1	0
<i>Sarcoptes scabiei</i> (Sarcoptic Mange)	3	1	0
PROTOZOA			
<i>Toxoplasma gondii</i> (Toxoplasmosis)	2	0	2
FUNGI			
<i>Encephalitozoon cuniculi</i> (Encephalitozoonosis)	1	0	0

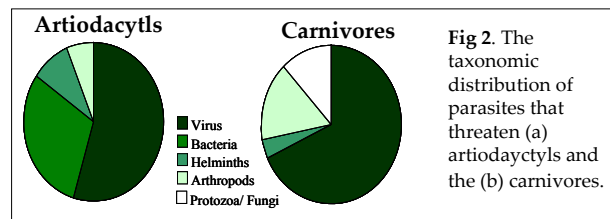


Fig 2. The taxonomic distribution of parasites that threaten (a) artiodactyls and (b) carnivores.

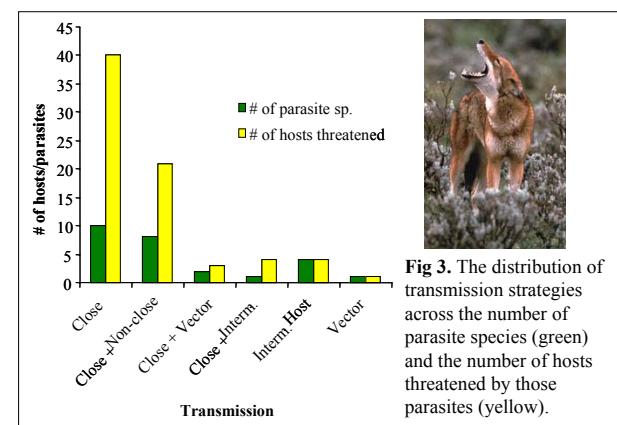


Fig 3. The distribution of transmission strategies across the number of parasite species (green) and the number of hosts threatened by those parasites (yellow).

Host specificity: Parasites threatening wild mammals were ALL multi-host parasites, and over 96% were shared with domesticated animals (cattle, pigs, sheep, goats, cats and dogs).

Transmission mode: There was a significantly higher proportion of parasites transmitted by close contact than by any other transmission route for both the total number of parasites and the number of parasite threatened host species (Fig. 3).

3. Threatened and endangered hosts are poorly sampled for infectious diseases

- Of the 51 mammalian species listed as threatened due to parasites/pathogens, independent assessments could only be obtained for 50% of the host species, and the causal parasite could not be identified from published literature or species assessments for 16 of the hosts.
- Of the 25 most threatened primate species, over 60% have no published references to any parasite or pathogen occurring in natural populations.

Significance and future directions

1. Clades most closely related to domesticated species have the highest risk of extinction by parasites. The artiodactyls and carnivores are the most heavily parasite-threatened mammalian orders, and within these orders there are more threatened species in the groups related to domesticated animals.
2. Specific pathogen characteristics may predispose them to threaten mammals. Viruses are the most likely parasite type to cause extinction risk, and nearly all of the pathogens listed were transmitted by close contact and were shared with a domesticated animal.
3. While we found significant correlates of host and parasite characteristics that may predispose parasites to be a threatening force, we also documented the paucity of published information that is currently known about parasites in endangered animal populations.
4. Infectious diseases, especially those that cross species boundaries, are a significant threat to biodiversity and conservation and need to be integrated into management and conservation plans.