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Biological Conservation 118 (2004) 397–401

BIOLOGICAL
CONSERVATION

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Parasite infection rates of impala (*Aepyceros melampus*) in fenced game reserves in relation to reserve characteristics

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Received 22 December 2002; received in revised form 22 May 2003; accepted 15 September 2003

Abstract

Under certain conditions reserves can pose a threat to wildlife conservation by increasing the transmission of parasites and pathogens. In this study, I investigated associations between reserve characteristics including area, density and species richness and parasite infection rates in impala (*Aepyceros melampus*). Using coprological methods to measure gastrointestinal parasitism rates of impala inhabiting five fully or partially fenced game reserves in central Kenya, I found that bovid species richness was correlated with parasite taxa richness across reserves, and that prevalence rates of multi-host strongyle nematodes were higher in reserves with more species. In addition, reserve size was also implicated as a potential predictor of infection risk. Overall, these results suggest that wildlife inhabiting highly diverse and small reserves may suffer from higher than normal rates of infection. Given the potential debilitating effects increases in parasitism can have on wildlife, these results underscore the importance of considering parasite transmission dynamics in the management of small, fenced protected areas.

Keywords: Impala; Protected ares; Reserves; Helminths; Multi-host parasites

1. Introduction

Increasing evidence suggests that parasites and disease are significant threats to wildlife populations and can act as important agents of extinction (Woodroffe, 1999; Daszak et al., 2000; Harvell et al., 2002). Ongoing efforts to protect wildlife from the expanding threat of extinction include the creation of a widening network of protected areas (reserves) worldwide. While reserves are in many cases an effective means of protecting wildlife from threats such as habitat degradation and direct exploitation (Caro et al., 1998; Bruner et al., 2001; McKinney, 2002), they can in certain circumstances enhance the spread of infectious diseases (Lafferty and Gerber, 2002).

There are many different types of protected areas and in Africa in particular, there has been a proliferation of relatively small, fenced game reserves as part of an effort to ensure the security of highly endangered species such as black (*Diceros bicornis*) and white (*Ceratotherium simum*) rhinos. These small enclosed reserves often house a high density and diversity of other species as well and past studies have suggested that compared to unprotected natural habitats, parasite cross-infestation between host species and the occurrence of parasitic diseases are often more common in these types of reserves (e.g. Pester and Laurence, 1974; Horak, 1980; Anderson, 1983; Boomker et al., 2000). Most likely, these effects are the direct result of close associations between species and increased spatial overlap between individuals within these areas, factors that both facilitate parasite transmission. Reserve features such as size, animal density and species diversity all potentially influence interactions between individuals and can affect contact rates between susceptible and infected hosts. Because contact rates are presumably higher in small, densely populated or highly diverse reserves, animals may be more vulnerable to infection in these settings.

My goal in this study was to explore the relationship between reserve design and parasitic infection. To do this, I assessed gastrointestinal parasitism levels of impala antelope (*A. melampus*) inhabiting entirely or partially fenced reserves in central Kenya, and evaluated the

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doi:10.1016/j.biocon.2003.09.016

effects of three reserve characteristics (area, bovid density, bovid species richness) on population infection rates.

2. Methods

To determine burdens of fecally transmitted gastrointestinal parasites in impala, I collected fecal samples from animals at five private and public reserves in Kenya including: Sweetwaters Game Reserve, Laikipia (24–28 November 1999); Lewa Downs Nature Conservancy, Laikipia (28–29 January 2000); Ol Jogi Game Reserve, Ol Jogi Ranch Ltd, Laikipia (18–21 May 2000); Kongoni Game Reserve, Naivasha (12–14 March 2001), and Lake Nakuru National Park, Nakuru (26–28 June 2001). Each reserve has a substantial impala population in addition to large populations of other bovid species such as buffalo (*Syncerus caffer*), waterbuck (*Kobus defassa*), Grant's gazelle (*Gazella granti*), Thomson's gazelle (*Gazella thomsoni*), hartebeest (*Alcelaphus buselaphus*), eland (*Taurotragus oryx*) and bushbuck (*Tragelaphus scriptus*). In addition, all of the reserves also house several ungulate species particularly targeted for protection, including African elephant (*Loxodonta africana*), black rhinoceros, white rhinoceros and Grevy's zebra (*Equus grevyi*).

At each reserve, I monitored several impala herds, following them until defecations occurred, and then I collected the fresh fecal samples in a labeled plastic bag. After collection, all samples were immediately placed in a cooler with ice packs or at 4 °C until they could be transported to the laboratory for processing. I used a modification of the McMaster dilution egg counting technique to quantify parasite loads in feces (MAFF, 1980; Ezenwa, 2003). Six different parasite taxa were distinguished during sampling including nematodes from the order Strongylida (strongyles), Protostrongylid lungworms and *Strongyloides* spp.; two cestodes, *Moniezia* spp. and *Thysaniezia* sp.; and protozoans from the class Coccidia (Table 1). Other than Lake Nakuru NP, all reserves were sampled during the dry season (<100 mm rain in the preceding three months) so seasonality is unlikely to have biased parasitological survey results across sites. The number of parasite taxa infecting each population was used as a measure of parasite richness. I also calculated the percentage of hosts in each population that were infected with strongyle nematodes and coccidia, the two most commonly observed parasite types, to determine the relative prevalence of these parasite taxa across reserves.

I tested the effects of three different reserve characteristics: reserve area (km^2), bovid density and bovid species richness on impala infection rates using simple and multiple regression analyses (Statview 5.0, SAS Institute). For each sampling location, demographic data (Table 2) were obtained from reserve managers and are based on the most recent on-site wildlife census performed prior to sampling. All prevalence data were acrsine transformed and relationships between strongyle and coccidia prevalence and reserve characteristics were tested with simple regressions. Because parasite taxa richness was correlated with sampling effort across reserves (parasite richness vs. no. fecal samples: $F_{1,4} = 24.6$, $r^2 = 0.89$, $p = 0.016$), I initially explored relationships between richness and reserve characteristics using multiple regression analyses that included sample size as a covariate. However, because of the small number of reserves being studied, I also analyzed the data with simple regression tests where I controlled for sample size by using the residuals of parasite richness and sample size as the dependent variable. Results of both sets of analyses are presented.

Table 1
Parasites identified from impala in five reserves in central Kenya

Parasite type	Sweetwaters ($n = 19$)	Lewa Downs ($n = 14$)	Ol Jogi ($n = 18$)	Kongoni ($n = 22$)	Lake Nakuru ($n = 26$)
Strongyles	X	X	X	X	X
Coccidia	X	X	X	X	X
Strongyloides spp.	X	X	X	X	X
Protostrongylids			X	X	X
Moniezia spp.				X	X
Thysaniezia sp.	X				

Table 2
Size, stocking rates and impala parasite infection rates for five reserves in central Kenya

Reserve	Area (km^2)	Total bovid density (individuals/km^2)	No. bovid species	Strongyle prevalence (%)	Coccidia prevalence (%)	No. parasite taxa
Ol Jogi	57	19.3	16	100	61	4
Kongoni	69	38.2	18	100	68	5
Sweetwaters	97	20.9	13	89	95	4
Lewa Downs	162	12.6	15	100	64	3
Lake Nakuru	188	34.8	10	88	50	5

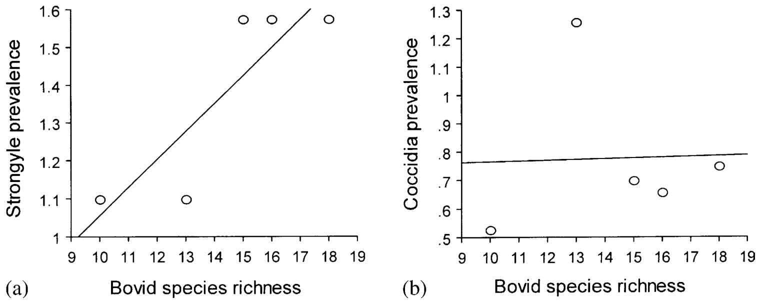

Fig. 1. Relationship between impala: (a) strongyle prevalence ($r^2 = 0.75$, $p = 0.056$) and (b) coccidia prevalence ($r^2 = 0.001$, $p = 0.96$) and the number of bovid species (bovid species richness) in reserves.

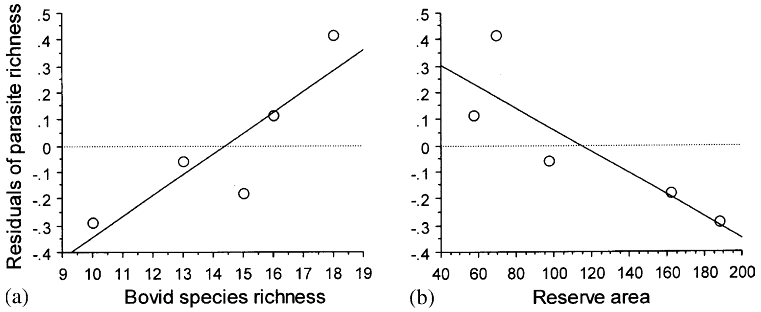

Fig. 2. Relationship between residuals of parasite richness and (a) bovid species richness ($r^2 = 0.76$, $p = 0.056$) and (b) reserve size ($r^2 = 0.73$, $p = 0.067$).

3. Results

Of the six parasite taxa detected in this study only strongyle nematodes and coccidia were found in all reserves. Strongyle prevalence ranged from 88% to 100% and coccidia prevalence was slightly lower, ranging from 50% to 95% (Table 2). Overall, each reserve population was infected with between 3 and 5 different parasite taxa (Table 2).

Strongyle prevalence was positively correlated with the number of bovid species occupying a reserve ($F_{1,4} = 9.18$, $r^2 = 0.75$, $p = 0.056$; Fig. 1(a)), however there was no correlation between coccidia prevalence and bovid species richness ($F_{1,4} = 0.003$, $r^2 = 0.001$, $p = 0.96$; Fig. 1(b)). Neither strongyle nor coccidia prevalence was correlated with bovid density (strongyles: $F_{1,4} = 0.16$, $r^2 = 0.05$, $p = 0.72$; coccidia: $F_{1,4} = 0.21$, $r^2 = 0.06$, $p = 0.68$) or reserve area (strongyles: $F_{1,4} = 0.72$, $r^2 = 0.19$, $p = 0.46$; coccidia: $F_{1,4} = 0.42$, $r^2 = 0.12$, $p = 0.56$).

In multiple regression analyses using sample size as a covariate, parasite taxa richness was positively correlated with bovid species richness (partial correlation coefficient, $r = 0.36$, $p = 0.028$), but not with reserve area ($r = -0.29$, $p = 0.13$) or bovid density ($r = 0.62$, $p = 0.17$). When these analyses were repeated with univariate methods, bovid species richness was significantly correlated with the residuals of parasite richness ($F_{1,4} = 9.22$, $r^2 = 0.76$, $p = 0.056$; Fig. 2(a)) and a marginally significant relationship emerged between parasite richness and reserve area ($F_{1,4} = 7.97$, $r^2 = 0.73$, $p = 0.067$; Fig. 2(b)). There was no correlation between bovid density and the residuals of parasite richness ($F_{1,4} = 0.48, r^2 = 0.14, p = 0.54$).

4. Discussion

Impala populations in reserves with more bovid species had higher parasite taxa richness and strongyle prevalence than populations in less diverse protected areas suggesting that animals in fenced, species-rich reserves are exposed to a wider range of fecally dispersed and potentially other contagious parasites. This probably comes about because in species-rich reserves, impala come into contact with a higher proportion of heterospecific individuals from which they can contract parasites. These contacts then result in more frequent parasite cross-transmission events and increased establishment of new parasite types within impala populations. Many helminth parasites of the Bovidae, strongyle nematodes in particular, are highly non-species specific and can infect multiple host species (Bindernagel, 1970; Waruiru et al., 1995; Boomker et al., 1986). Previous work in a non-reserve setting has shown that habitat overlap between bovids is associated with increased strongyle infection rates (Ezenwa, 2003), indicating that cross-transmission is an important component of the transmission dynamics of these parasites. For this reason, animals in highly diverse reserves where overlap between species is high are more vulnerable to infection by parasites able to exploit multiple host species. Infection rates with species-specific parasites, on the other hand, should not be influenced by reserve diversity because cross-species transmission is unlikely to play a large role in the transmission dynamics of these types of parasites. Thus, it is not surprising that coccidia prevalence was not correlated with bovid species richness in this study, since unlike strongyles, coccidia are a relatively more host-specific group (Levine and Ivens, 1986).

Interestingly, generalist parasites are far more likely than specialists to cause disease outbreaks and extinctions particularly in small host populations (Cleaveland et al., 2002; Woodroffe, 1999), therefore the implications of having increased multi-host parasite prevalence in species-rich reserves are potentially far-reaching. Generalists have these types of effects because large reservoir populations acting as maintenance hosts can facilitate the spill-over of these parasites into small, threatened host groups leading to massive die-offs or extirpation (Lyles and Dobson, 1993; Daszak et al., 2000). Results detailed in this study suggest that in fenced, highly diverse reserves certain types of parasites may be able to move quickly between species, potentially posing a serious threat to small resident populations. In protected areas housing endangered or threatened species, like many of the reserves in the present study, this means that the introduction of new parasites must be carefully guarded against. For example, because common management practices such as wildlife translocation can inadvertently introduce foreign parasites into new habitats (e.g. Fernandez-de-Mera et al., 2003) routine parasite screening of new transports and appropriate sentinel species could be a valuable tool not only for monitoring species health, but for protecting against the establishment and dissemination of new parasites within otherwise closed systems.

In addition to bovid species richness, reserve size also emerged as a potentially important factor influencing infection risk. Analyses show a strong trend toward increasing parasite richness in smaller reserves suggesting that parasite cross-transmission may be amplified in small areas. This phenomenon is likely due to increased spatial overlap and therefore parasite cross-transmission among species confined to smaller spaces. In addition to this direct effect, small reserve size can potentially impact host infection risk indirectly as well. In small, fenced reserves, factors such as restricted movement, reduced resource availability and disrupted social structure can act as stressors that may contribute to the spread of disease. When animals are debilitated by any form of stress, immune function can become compromised (e.g. Stefanski, 2001) making them not only more susceptible to parasites but also allowing previously inconsequential infections to cause severe disease. This interaction between parasitism and stress could very well contribute significantly to the mortality of animals within small reserves. As such, future work focusing on understanding the inter-relationships between stress, reserve design and infectious disease could have important implications for wildlife health.

To my knowledge, this is the first study to show a direct link between specific reserve characteristics and parasite infection rates. Although additional work looking at a larger set of reserves is required to test the robustness of these patterns, results detailed in the present study strongly suggest that animals in fenced reserves that are highly diverse and small have elevated parasite infection risks, a fact which could have nontrivial consequences in cases where new multi-host parasites invade naïve host populations or existing parasites increase substantially in prevalence among current hosts. Even though an increase in parasitism does not always represent a threat to host survival, increases in infection rates combined with other factors to which animals may be exposed in small, confined reserves can potentially have significant impacts on the well-being of wildlife populations within these types of protected areas. In light of this fact, it is important for parasite transmission dynamics to be considered during reserve planning and management, particularly in small, fenced reserves seeking to maintain a healthy environment for threatened species.

Acknowledgements

I thank the Office of the President of Kenya for providing permission to carry out this work in Kenya, and Sweetwaters GR, Lewa Downs Conservancy, Kongoni GR, Ol Jogi GR, and the Kenya Wildlife Service (Lake Nakuru NP) for permission to conduct sampling. T. DeMaar (Ol Jogi), N. Georgiadis and C. Nunez provided assistance with logistics and sampling. This work was supported by a NSF predoctoral fellowship, a Fulbright fellowship, an EPA STAR graduate fellowship, and the Department of Ecology and Evolutionary Biology, Princeton University.

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