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Original Contribution

Parasite Threat to Panda Conservation

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Abstract: The giant panda is a global symbol of wildlife conservation that is threatened by historic and current habitat loss. Despite a great deal of research on the physiology, reproductive biology, and diet of pandas in the wild and in captivity, there is little information on wild panda mortality. Here we integrate previously unavailable data on the mortality of wild pandas. We report on three recent phases of panda mortality: deaths due to bamboo flowering in the 1970s and 1980s, surprisingly extensive poaching in the 1980s and 1990s, and a parasitic infection over the past few years. Our analyses suggest that the current most significant threat to wild panda survival is disease due to extraintestinal migration (visceral larval migrans) by an ascarid nematode. We demonstrate that the probability of death of wild pandas being caused by this disease increased significantly between 1971 and 2005 and discuss the possible factors leading to the emergence of this disease.

Keywords: giant panda, parasite, conservation, mortality, emerging infectious diseases, China

Introduction

The giant panda (*Ailuropoda melanoleuca*) is an endangered species endemic in China and considered a flagship species for conservation (O'Brien et al., 1994; Peng et al., 2001a). The Chinese government initiated protection in 1957 and listed the panda as Category I in the List of Key Protected Wildlife, an appendix within the Law of the People's Republic of China on the Protection of Wildlife in 1989. The giant panda was listed by the IUCN Species Survival Commission (SSC) as "Rare" in 1986 and 1988 and "Endangered" in 1990, 1994, and 1996 (Species Survival Commission, 2004). The most significant threats listed by the Bear Specialist Group of the SSC are habitat loss/degradation, harvesting (hunting), accidental mortality, and intrinsic factors (poor reproduction and low densities). The latest assessment of this species was in 2004 and it was listed as "Endangered," with the main threats being habitat loss, degradation, and fragmentation (Wang and Xie, 2004).

Some authors have cited other factors that may threaten this species such as capturing for zoos and/or breeding centers (Hu, 1998), starvation induced by natural collapses of bamboo populations (flowering followed by death) (Yang et al., 1981; Reid et al., 1989), illegal trade or poaching for fur and skull collection (Hu, 1998; Li et al., 2003), and diseases (Feng et al., 1985).

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Despite recent advances in the understanding of giant panda biology in captivity (Qiu and Mainka, 1993; Peng et al., 2001b) and in the wild (Lü et al., 2001; Lindburg and Baragona, 2004), few studies have investigated trends in wild panda mortality. Furthermore, a number of recent papers have identified diseases as important threats to the conservation of wildlife (Dobson and May, 1986; May, 1988; Meffe, 1999; Daszak et al., 2000). While a number of diseases in captive pandas have been reported and described (Hu, 2001), there are relatively few published reports of diseases in wild individuals.

Here we analyze previously unavailable reports on the causes of panda mortality in the wild from 1971 to 2005. These include extensive parasitologic and pathologic data from postmortem examinations of pandas that have not previously been published. We use these data to analyze trends in giant panda mortality and identify a parasitic infection as the most significant current threat to wild panda survival.

Materials and Methods

We collected data on the mortality of wild giant pandas from articles published in Chinese scientific journals, government magazines, and newspapers and reports compiled by the Chinese government and organizations, as well as government websites and personal communications (supplmental information). Two coauthors of this article (HLH and GYY) provided data from unpublished postmortem examinations of panda carcasses.

We identified four major causes of death listed in these articles and reports: parasitic infection (listed as "roundworm" or "VLM"), poaching (often reported by government newspapers and magazine articles), starvation, and old age. We note that there may be several parasitic worms that cause panda mortality. We included only cases where the cause of death was listed as parasitic infection when significant pathologic damage to vital organs was identified on postmortem examination by a qualified veterinary pathologist. Although we restricted the analysis to mortality with known causes, we cannot rule out the possibility that surveillance for some causes differed over the study period. It is also possible that some errors may have occurred in assessing the cause of mortality. We used binary logistic regression to analyze temporal trends in the probability of pandas dying from each of the four causes of death.

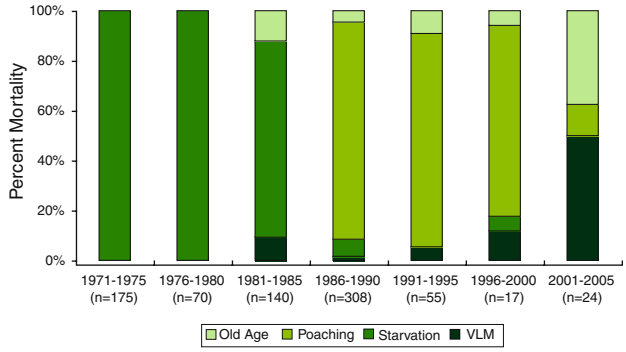

Figure 1. Temporal variation in causes of mortality of Giant Pandas. VLM = visceral larval migrans due to *B. schroederi*.

Results

We examined reports on the cause of death of 789 adult pandas that died in their natural habitats between 1971 and 2005 (Fig. 1; Supplemental Information). We report three trends in mortality over this 35-year period. First, a period of heavy mortality during the 1970s and early 1980s due to starvation (355/385 or 92% ± SE 1.4% of deaths from 1971 to 1985); subsequently, the probability of pandas dying of starvation significantly decreased (logistic regression on year of death, 1971–2005: coeff. = −0.966; n = 789; $P <$ 0.001). A second factor, poaching, was responsible for 86 ± 1.8% (328/380) of deaths between 1986 and 2000 (Fig. 1). However, the probability of pandas dying from poaching decreased significantly from 1986 to 2005 (coeff. = −0.143; n = 404; $P <$ 0.001). Finally, visceral larval migrans (VLM) due to the nematode *Baylisascaris schroederi* or another parasitic worm represented the most important cause of death during the most recent period (2001–2005), responsible for 50 ± 10.2% (12/24) of the deaths reported. The probability of death from this pathogen increased significantly between 1971 and 2005 (coeff. = 0.143; n = 789; $P <$ 0.001), as did the probability of pandas dying from old age (coeff. = 0.117; n = 789; $P <$ 0.001).

Discussion

Our analyses suggest that the significance of three major threats to panda survival in the wild has changed over the past 35 years. The first, starvation, correlates with the widely reported simultaneous flowering and death of bamboo across large areas of panda habitat (Fox, 1984). The impact of bamboo flowering was likely exacerbated by habitat fragmentation and loss which may have limited

migration of pandas to areas with available food (Peng et al., 2001a). The second threat reflects a rise in the poaching of pandas for skins and skulls. This has occurred historically in China and has previously been cited as a serious and probably underreported threat to panda conservation (Li et al., 2003). The reversal of this threat was likely in response to policy changes enacted by the Law of the People's Republic of China on the Protection of Wildlife (1989) in which the state government invoked severe penalties for poaching. Punishments meted out to hunters and traffickers in panda skins or parts have included life imprisonment or the death penalty (Li et al., 2003).

In the third and current phase, a parasitic disease due to visceral larval migrans (VLM) is the most significant cause of death, albeit that the overall numbers of mortalities are lower than in the earlier phases. In pandas that died of VLM, nematodes identified as *Baylisascaris schroederi* were recovered from the liver, lungs, heart, and brain. Individuals often exhibited heavy intestinal worm burdens leading to intestinal inflammation and metabolic disorders. In our study, infection by *B. schroederi* was listed as a cause of death when significant pathologic damage to vital organs was identified on postmortem examination by a qualified veterinary pathologist. The nematode *Baylisascaris schroederi* was first reported by McIntosh (1939) from the intestinal tract of wild giant pandas and has been previously implicated as the cause of limited mortality (Hu, 2001). Nematodes such as *B. schroederi* typically reside in the intestinal tract of their host. Visceral larval migrans (VLM) is a disease that occurs when nematodes undergo aberrant migration within a host, most commonly when nematodes infect hosts that are not part of their natural life cycle. For example, VLM causes significant disease in people infected by the dog nematode *Toxocara canis* (Wolfe and Wright, 2003), the raccoon nematode *Baylisascaris procyonis* (Murray and Kazacos, 2004) and others. In VLM due to *Baylisascaris* spp., larval nematodes can be observed in the liver, lungs, heart, and brain, with clinical severity and pathologic manifestations depending primarily on the number and location of larvae, duration of infection, occurrence of reinfection, and the host's immunologic condition (Beaver, 1969; Elizabeth and Keystone, 1996).

The increase in the fraction of parasite-related deaths in a period where other threats have been reduced suggests that this parasite represents a significant threat to panda conservation. We hypothesize that the underlying driver of this disease is related to a relative increase in panda density as the population has been forced to inhabit remnant patches of bamboo forest. Data suggest that the population of wild pandas has likely increased over the study period from 1075 in 1974–1977 to 1114 in 1985–1989 and to the current number of about 1590 adult individuals in 1999–2004 (State Forestry Administration and WWF, 2005; Yu, 2005). This is a mean annual increase of 1.7%. However, between May 1974 and August 1985 available wild panda habitat decreased from 29,500 km^2 to 13,000 km^2, a loss of more than 50% (Liu et al., 2001; Lü and Elizabeth, 2001). This represents a fourfold increase in the density of pandas from 3.6 to 12.2 per 100 km^2. Pandas can become infected by *B. schroederi* through two fecal–oral routes: (1) by walking on fecally contaminated ground, the eggs adhere to the feet and then enter the panda's mouth when it manipulates bamboo, and (2) pandas communicate territorial boundaries by marking trees with urine and/or feces; when an individual nuzzles or licks the mark, parasites can by transmitted. Increasing density of pandas would likely result in increased transmission of this pathogen via both these pathways.

An alternative hypothesis is that the giant panda is not the natural host of the *Baylisascaris* sp. reported in these postmortem examinations, and possibly in the original description (McIntosh, 1939). The raccoon nematode *B. procyonis* causes VLM in some rodent species and has been cited as contributing to the decline of the Allegheny woodrat (*Neotoma magister*) in North America (LoGiudice, 2003). Like the giant panda, the multidecade decline of the Allegheny woodrat was caused by a series of factors that differed in significance over time, including deforestation, habitat loss and modification, the introduction of exotic pathogens, and *B. procyonis* (LoGiudice, 2006). In the case of the giant panda, it is possible that long-term habitat loss and degradation has led to increased density of alternative hosts for this nematode, increasing the prevalence of the parasite in pandas and the intensity of infections. To resolve the underlying cause of the emergence of VLM as a threat to panda survival, future panda conservation efforts should include detailed examination of the ecology of this host-parasite assembly, with particular attention to density-dependent transmission. They should also include an accurate description of the life cycle of the parasite and the identification of alternative hosts.

The success of the giant panda conservation program has relied on efforts from Chinese central and local governments as well as numerous international organizations. As part of these conservation programs, studies have been conducted on the biology, breeding, and reproduction in captivity and the habitat of giant pandas (see review articles, e.g., Hu, 1989, 1997, 1998, 2001; Lindburg and Bar-

agona, 2004; Pan et al., 1988, 2001; Schaller, 1994; Schaller et al., 1985). Our analyses demonstrate the importance of investigations of mortality trends in identifying threats to the conservation of this and other species, and therefore in developing effective conservation strategy. Our study also adds yet another disease to the growing list of emerging infectious diseases that threaten the conservation of wildlife (Meffe, 1999; Daszak et al., 2000).

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