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Lions, Conflict and Conservation in Eastern and Southern Africa

**BACKGROUND PAPER FOR THE EASTERN AND SOUTHERN AFRICAN LION
CONSERVATION WORKSHOP, JOHANNESBURG, SOUTH AFRICA, 11-13 JANUARY 2006**

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Although we have no reliable data on Africa-wide lion populations prior to the late 20th century, there is wide agreement that numbers have been in steady decline, and are no doubt at an all-time low; estimates based on local experts' best guesses and estimates range between 16,500 and 47,000 (Chardonnet, 2002; Bauer and van der Merwe, 2004). Lions have been totally eliminated in North Africa, and only relict populations remain in West and Central Africa (ibid). Half of the remaining population is in one country, Tanzania, and smaller viable populations remain in Kenya, South Africa, Mozambique, Botswana, Zimbabwe, Zambia and Namibia.

As with the world's other large carnivores, the reduction in lion populations has been largely due to conflict with humans over livestock. Large carnivores kill livestock and are in turn killed by livestock owners or herders. Lions also attack people, and even in the 21st Century man-eating is a serious problem in Ethiopia, Tanzania and Mozambique. Reports in the popular press have implicated Feline Immunodeficiency Virus (FIV) and sport hunting as playing roles in the decline but there is little supporting data; FIV is notable for its apparent lack of clinical effects on individuals, and there is no credible evidence that it poses any threat to wild populations (Packer, et al. 1999, Troyer et al., 2005). One report has blamed a local population decline on poorly regulated trophy hunting (Loveridge and Macdonald, 2003), but this problem appears to be restricted to Zimbabwe (see Packer, et al. this volume) and extensive retaliatory killing, snaring and habitat loss in the surrounding area are likely to be the major conservation risks to lions. Our opinion is that retaliatory and pre-emptive killing of lions by rural people, particularly livestock owners is the single greatest threat to lion populations.

European settlement of Africa had a major impact on wildlife generally and predators in particular. Because they readily prey on livestock, large carnivores were considered vermin (they are still legally classified as such in some countries), and settlers made great efforts to exterminate them in farming and ranching areas. These killings were exacerbated by a burgeoning demand for exotic wildlife products such as skins and ivory. Lion and other wildlife populations were viewed as inexhaustible and exploited as rapidly as they were encountered. As an example of the zeal with which lions were shot, safaris to the Serengeti area in the early part of the last century sometimes shot over 100 lions (Turner, 1987), clients of just one safari company killed 700-800 lions in 1911 (Herne, 1999) and in 1908, over 150 lions were killed 'on license' in Laikipia District, Kenya, alone (Playne, 1909). This scale of slaughter was not exclusive to the early twentieth century: in Southern Africa the large scale slaughter of wildlife kicked off in the early 1800's and between 1946-1952, one Laikipia game warden shot 434 lions 'on control' (Herne, 1999), and several individuals killed over 300 lions apiece in the course of ranching in Kenya in the 1970's and 80's (Anonymous, pers. comm.). By the 1960s, lions in South Africa were restricted to just two National Parks: Kruger and the Kalahari.

Much of this killing no doubt took the form of 'sport', but was motivated primarily by the perceived need to protect domestic animals. Although ranchers in East Africa used traditional African cattle husbandry methods which effectively minimized losses (below), western practice was to eliminate predators rather than try to live with them. Poison (strychnine and organophosphate cattle dips) was used very widely on East African ranches, continuing well into the latter half of the twentieth century (Denney, 1972) and is still reportedly used by a small minority of commercial ranchers. At least until very recently, the Kenya Wildlife Service and the Kenya Veterinary Department poisoned hyenas on a wide scale, no doubt affecting lions and other scavengers as well. A very worrying development has been the increasing use of the soil dressing Furadan (carbofuran), to kill predators in some traditional pastoralist areas of Kenya (Frank, unpub. data). Although shooting can target specific problem animals, poison is indiscriminate and often removes whole prides at once, as well as large numbers of other predators and scavengers (Jenkins, P. 2001). The Kenya Veterinary Department appears to be restricting availability of strychnine, but Furadan is widely available, cheap, and thought to be the poison of choice for eliminating predators. During a recent ban on lion killing in Botswana, several reports of poisoning appeared in the popular press and one was recorded and reported by GH (Hemson, 2003). Subsequent observations and conversations with wildlife officials made it apparent how difficult it was to identify and prosecute poisoners (it being illegal in Botswana).

Spearing and poisoning in retaliation for livestock depredation appears to be decimating lion numbers in southern Kenya. Masailand comprises about 93,000 km² of grassland, including Serengeti National Park

and the Ngorongoro Conservation Area in northern Tanzania, the Masai Mara National Reserve and Amboseli National Park in southern Kenya, and vast tracts of unprotected country in between. This region is inhabited by traditional Masai pastoralists with their large herds of cattle. Because of the large amount of wildlife and these world famous protected areas, it is one of the most important remaining semi-natural ecosystems in East Africa. It has also been home to what is probably the single biggest contiguous lion population in Africa. We have no good numbers on the lion population outside of protected areas, but several well-documented local situations suggest that lions are now under very severe human pressure, and that we may be in imminent danger of losing them outside parks in this entire region. The lions of Nairobi National Park and the adjacent Kitengela Plains were decimated by a rash of spearing by Masai morans (warriors) that killed at least 87 lions since 1998 (Ogutu, 2005) allegedly in retaliation for attacks on livestock. Due to the lack of land-use planning around the Park, development and fencing have severely reduced natural prey in the region. A recent study by Ogutu et al (2005) found that the lion density to the north of the Masai Mara National Reserve was only 12% that of the reserve itself; until recently, lions were abundant throughout the rangelands adjacent to the Reserve (LGF, unpub. data). Richard Bonham has documented a minimum of 76 lion killings (using poison or spears) since early 2001 and a drastic decline in lion sightings on and around Mbirikani Group Ranch in southeast Kenya, between Amboseli and Tsavo National Parks. In Tanzania, Bernard Kissui (in preparation) has documented over 125 lion killings between 2000-2005 in the greater Tarangire-Manyara ecosystem, and Dennis Ikanda (2005) reported 35 lions killed in the Ngorongoro Conservation Area between 1998-2004. Thus, the same pattern is occurring in a wide range of areas; elsewhere in Masailand, no one has been counting.

The reasons behind this apparent increased intolerance of predators are not entirely clear but are currently under study (Lamprey and Reid, 2003; L. Hazzah, unpub. data; S. Rodriguez, unpub. data). Masai socioeconomics are rapidly changing under the interrelated influences of land subdivision, ever-growing populations, developing participation in a cash economy, the influence of missionaries, and increased politicization. Suppression of cattle raiding has deprived morans of their traditional youthful pursuits, leaving lion killing as the sole remaining way to test their bravery. In Kenya, the problem may be compounded by the fact that, in the absence of trophy hunting, wildlife outside of parks has no financial value.

While this is an extreme example of lion intolerance, killing of lions for livestock losses and threat to human life is near ubiquitous in Sub-Saharan Africa. In Mozambique lion-human conflict is a source of livestock and lion mortality in all four provinces (Anderson and Pariela, 2005 and below) and popular press reports from Zambia indicate the problem occurs widely (The Times of Zambia, November 2005).

In Namibia human lion livestock is restricted to areas surrounding Etosha, Kaudom, Caprivi and adjacent to the Southern Kalahari with a small population occasionally problematic in the Skeleton Coast (Stander and Hanssen, 2003). In Botswana, reprisal killings of lions in response to lion depredation on livestock led to a total ban on lion hunting in 2000. Indeed it is reasonable to conclude that lions and other predators are being killed in all major range states in response to their depredations on livestock.

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In some areas such as the Okavango Delta, large source populations and low human densities might sometimes mean that the human threat to lion population integrity is limited. However, long-term viability of the lion population may not be sustainable in areas of high human and low lion density, e.g. Makgadikgadi, the Southern Kalahari, and Masailand. Even populations as large as 500 animals may become unsustainable in the face of stochastic environmental variation if persecuted by people and completely isolated from more robust sources (>1000 animals). There appear to be only five or six populations that large in all of Africa (Kruger, Okavango, Serengeti, Selous, Moyowosi/Rungwa, and possibly Tsavo). It is reasonable to conclude that direct killing threatens lion populations in smaller reserves and outside large protected areas today, and in the long term threatens almost all lions as metapopulation connections are broken down.

Costs

In spite of its overwhelming importance in lion conservation, there has been remarkably little research on lion-human conflict. Laikipia District, Kenya, is a conservation success, with abundant wildlife, including predators, living on commercial livestock ranches. Both commercial ranchers and Mukogodo-Masai pastoralists use traditional African livestock husbandry techniques: cattle, sheep, goats and camels are closely herded by men and dogs as they graze by day, and at dusk are brought back into thornbush bomas (kraals) with people living in huts around them. On the commercial ranches, Frank (1998) found that lions took 0.51% of cattle and 0.27% of sheep annually. In 1996, it cost \$300-\$400 in lost livestock to support a lion on the commercial ranches of Laikipia; improved husbandry in recent years has decreased losses on most ranches. Data from one Laikipia group ranch and one settlement scheme (both communally owned by Mukogodo Masai pastoralists) showed losses of 0.69 % of their cattle and 1.40% of sheep and goats annually to predators, largely spotted hyenas. This may be compared to figures calculated from Butler (2000) for communal lands in Zimbabwe, in which 1.2% of cattle and 3.4% of shoats were taken by predators. By contrast, lions on Mbirikani Group Ranch in Masailand of southern Kenya take less than 0.01% of cattle; we do not know if this is representative of 'normal' conditions, because that lion population has been reduced by an estimated 60-80% through massive persecution in the last four years (MacLennan and Frank unpub. data).

While losses of livestock may be similarly low in many areas, means do not tell the entire story. In the Makgadikgadi of Botswana, livestock losses were not spread homogeneously through the population. Rather people living nearer the protected area (and the main lion population) lost more livestock than those further away (Hemson, 2003). While this cost was unevenly distributed, revenues from tourism were spread throughout the community, leaving an imbalance and creating ill feeling among those people living closest to the threat. To the community and to many farmers, attacks on livestock killings are unpredictable events of variable impact; occasionally lions destroy a family's livelihood in one night. In one example, a pair of resident adult males killed 43 goats at once, creating one irate farmer whose attitudes fell well outside the mean for his population. In these situations, the availability of nonspecific and highly effective poisons and traps creates the likelihood of collateral damage to all local carnivores. Indeed, it may be significant to note that while spotted hyenas were seen at the beginning of the Makgadikgadi study they were not encountered at all in the last year (Hemson and MacLennan pers. obs).

In this same study, only people actually employed in tourism were significantly less likely to want to remove lions and more open to co-existing with them. Here, tourism created opportunities and wealth but when divided amongst the community at large did not create enough positive association to engender any community-wide protective sentiment towards predators. While the situation may be different in areas of extremely high aesthetic value and low human populations such as the Okavango, similar or worse situations may exist in many areas in which lions are most threatened, (Harcourt, Parks and Woodroffe, 2001).

Depredation Circumstances

In Kenya and Botswana, the great majority of lion depredation occurs at night (Frank, 1998; Ogada et al., 2003, Hemson, 2003). In Kenya, lions most frequently approach a boma, causing the cattle inside to panic. If the boma is not sufficiently strong, or if it has weak points (most often the 'gate' which may be just a bush pulled into the opening), the cattle stampede, burst out of the boma, and flee into the bush where they might be taken by the lions or by hyenas; rounding them up often takes several men and vehicles most of the next day. Aside from the actual loss of cattle killed, ranchers complain that the stress causes loss of weight, and hence, profit. Depending on the structure of the boma (below) some lions may learn to leap over the wall, particularly when taking small stock.

In Botswana, livestock are frequently not herded and are often left to wander outside enclosures at night. As a result, while people did complain that lions raided their enclosures, the majority of kills recorded were away from the enclosures. Indeed data from GPS collared cattle and interviews suggested that between 13-20% of livestock were wandering around untended at night, making depredation almost

inevitable. Reports from the Southern Kalahari, Okavango and Khutse suggest similar patterns. In this situation, it is unsurprising to learn that enclosure structure had no significant influence over stock losses (Hemson, 2003).

Less commonly, lions take stock by day. This seems to be more opportunistic than taking them from bomas at night, and probably occurs when a herd inadvertently wanders into lions sleeping in the bush. Most ranchers consider this to be simply bad luck, and do not hunt down the responsible lions. On one ranch which halted all lion shooting, however, lions learned that they could take stock by day with impunity, and losses rose to 79 cattle in one year.

Data from Laikipia (Woodroffe and Frank, 2005) and from the Tsavo region (Patterson et al., 2004) support ranchers' and pastoralists' reports that livestock losses are higher during rainy periods. We saw few losses to predators during a severe multi-year drought, but losses skyrocketed when the rains finally came and many lions were shot in response. We speculate that listless wild prey and ready availability of carcasses during dry periods provide easy meals, but that lions are likely to turn to livestock when abundant grass makes wildlife harder to catch. In the Makgadikgadi and Ngorongoro Conservation Area, clear seasonal trends in livestock predation were recorded. These were related to wild prey availability and stock raiding decreased when migratory wild prey was present in large numbers despite local increases in lion populations. As migrant zebra and wildebeest moved to other areas local livestock predation increased despite a local decline in lion density (Hemson, 2003; Ikanda 2005). In this case some lions remained resident in areas in which they could kill wild prey when it was abundant and livestock when migrants were scarce. Another subset of the population tracked the wild migratory prey throughout the year and rarely encountered livestock.

During a prolonged drought in Makgadikgadi, livestock were left to wander untended for days and weeks to allow them to find fodder. The more mobile lions began to encounter livestock throughout the park and evidence from the very end of the project suggested that these newly acclimated lions subsequently became resident livestock killers.

Although Stander and Anderson (1981) suggested that subadult males are most likely to become livestock killers, it was apparent in all our study areas, that all lions are potential livestock killers. While subadults can be a major source of livestock loss in some areas, these situations tend to occur some distance away from protected areas or on the boundaries of protected areas with very hard edges such as fences. Closer to soft-edged protected areas, in multi-use landscapes and in unprotected areas with viable lion populations (as opposed to scattered sub-adults) all age-sex classes are known to kill

livestock. Although sub-adult males may be more likely to become livestock killers, these animals may be important to maintaining the genetic integrity of otherwise isolated regions of a metapopulation (e.g. Sweanor, Logan and Hornocker, 2000). One sub-adult male in Botswana moved approximately 400km after collaring (Hemson, 2003).

Lethal Control

Although Laikipia ranchers are remarkably tolerant of predators and willing to absorb a certain amount of loss, they do shoot persistent stock raiders, usually by tracking lions from a kill or by 'sitting up', waiting for them to return to the carcass of a cow killed the night before. This is highly selective; 'innocent' lions are rarely shot. Between 1998 and 2002, an average of 19.4% of the adult population was shot annually, amounting to 30-40 lions per year, equally divided among males and females (Frank, 1998; Woodroffe and Frank, 2004). Although this seems very high, the population appears to be stable at a density of 6-7 lions /100 km² (unpub data): cub survival is high and the only emaciated lions we have seen have been very old solitary individuals. Laikipia has abundant wild prey throughout the year which form the bulk of the lions' diet, even though wild ungulates are outnumbered ten to one by livestock (Georgiadis, Olwero and Ojwang' 2003).

Importantly, lions originally collared in association with livestock kills were nearly four times more likely to be shot in response to subsequent livestock damage than were lions collared on wildlife kills (12.9% vs. 49.0%), strongly supporting ranchers' contention that certain individuals or prides are chronic livestock killers while others are not. More generally, ranches with good livestock husbandry rarely lose stock and rarely shoot lions, while both livestock and lions are killed at higher rates on ranches with poor practices. Given that most lions move over several ranches (which average 132 km² in size), Woodroffe and Frank demonstrated that a single ranch which kills many lions serves as a local sink, draining lions from a much larger area. Thus, if a community of landowners wants to support predators, all members must practice similar levels of husbandry.

Due to the high mortality rate of stock-killing females, those not known to take livestock had four times higher cub production (0.981 cub/female/year vs. 0.231 cub/female/year) and 2.7 times higher cub survival than did stock killers. Moreover, this population is producing a skewed cub sex ratio, 69:31 favoring males. It is not known whether this is an effect of high mortality or other ecological factors.

Solutions

Ogada et al. (2003) assessed the efficacy of traditional African methods of livestock husbandry in protecting livestock from predators on commercial ranches. These practices evolved in response to the twin threats of both predators and livestock-stealing humans, and are thought to have remained relatively unchanged for thousands of years (Marshall, 1990). Not surprisingly, Ogada et al. (2003) found that ranchers kill significantly more predators on ranches where predators kill more livestock. Thus, implementation of any practice that reduces the vulnerability of livestock is critically important for reducing retaliatory killing of predators. Seventy-five percent of depredation on cattle, sheep and goats took place at night, and lions were responsible for over 75% of the total; predation in East African ranches occurs largely at the boma. Well-built bomas effectively constrain cattle and keep predators out. Bomas in Laikipia are made from native thornbush, stone walls, wooden posts or wire mesh (which is used for merino sheep); of these, thick strong thornbush was most effective at keeping lions out and panicked cattle in. Stone is an excellent building material if there is a fence on top to prevent lions from leaping onto the wall and into the boma. Although most expensive to build, stone bomas last essentially forever and need no maintenance. Wire mesh is a very poor barrier if not well-supported, but one Laikipia ranch has developed a modular, moveable fence made of 8x4x4 foot panels of mesh welded into interconnecting angle iron frames that is highly resistant to predators and easily transported.

Thornbush bomas are most effective if divided into inner 'rooms' that make it harder for cattle to reach the main gate, and the gate must be very strong, preferably made from lumber. The normal practice of using a tree or bush as a gate is ineffective, as it does not contain panicked cattle and allows hyenas to enter.

We found that lions are reluctant to approach bomas that are located in close proximity to large numbers of people. However, for security and environmental reasons, some ranches do not allow herders to have their families at the bomas. Of course, in traditional societies bomas usually have large numbers of people and dogs. Dogs are also highly effective deterrents; they do not chase predators, but warn of their approach, waking the herders who then chase the lions. Again, however, some ranches do not allow dogs, as herders will use them for hunting wild game. Dogs can carry lethal carnivore diseases, but they are such an effective deterrent that vaccinated dogs are an essential component of livestock husbandry. A bright light or noise-making device like a shotgun or thunderflash is also very helpful at discouraging loitering lions.

Different techniques must be employed in areas where livestock are often left out at night. While 88% of livestock owners in the Makgadikgadi thought they were responsible for their livestock, only 15% thought they were responsible for their losses to lions and 80% thought that the government was responsible for livestock losses. We suspect that a poorly conceived compensation system may have played a role in

this situation in Botswana: farmers were essentially free to remove predators at will and received a payment for lost livestock without any husbandry conditions being met. Consequently, the most economically effective way to limit financial losses was to remove predators, accept any compensation offered, and, if the owner could afford it, pay someone the bare minimum to look after livestock while the owner worked for cash elsewhere. An analogous situation was highlighted by Swenson and Andren (2005) in Norway. Here the government pays compensation regardless of the efforts taken to protect livestock and pays slightly under market value. Neighboring Sweden pays over the market value but insists farmers adopt state sanctioned methods for preventing livestock losses. Despite paying more per predation, Swedish farmers lose much less livestock per carnivore and Sweden has much healthier carnivore populations. The Swedish approach encourages and rewards better livestock care whereas the Norwegian and Botswana style lacks any such incentive.

One general trend emerging from studies of carnivore human conflict is that livestock killing seems most frequent in areas of extremely scarce wild prey. In some cases it is seems possible that wild prey may be scarce because people are hunting it and that the link between this hunting and livestock predation needs to be made clear. If communities were aware of this correlation, farmers might exert pressure on local hunters directly through community.

Problem Animal Control

In the absence of totally reliable methods for protecting livestock from lions, some amount of depredation is inevitable and some lions will form the habit of killing livestock. There is as yet no alternative to lethal removal of chronic offenders through Problem Animal Control; we strongly recommend against the common practice of 'translocating' problem predators to parks, as translocated predators often sustain damage in the trap, rarely stay where they are released, and usually end up being killed after causing further problems as they try to find their way home (P. Jenkins, 1997; LGF, unpub. data). Most commercial ranchers are able to deal with problem lions but small scale rural farmers and pastoralists usually do not have the means. In Kenya, rural people consistently complain that wildlife authorities do not react effectively when people report chronic stock raiders, leading to resentment not only against government but also against wildlife, conservation, and tourism. A well-trained and reliable PAC team, able to respond efficiently, effectively and rapidly, is an essential element of large carnivore management in livestock areas, but few countries have them. In their absence, rural people have little alternative besides such indiscriminate methods as poisoning, which probably poses the most serious threat to predator populations. PAC teams should be trained not only in humane removal, but also in the reliable identification of problem animals and especially in educating rural people in livestock husbandry techniques that better protect stock.

Conflict Resolution

Conflict with humans over livestock depredation is the single most important factor causing the decline in African lion populations. With growing numbers of people and livestock throughout the continent, lions will become entirely restricted to very large or well-managed protected areas if conflict mitigation cannot be implemented on a wide scale. Ancient methods of livestock husbandry are remarkably effective at minimizing conflict, but these are rapidly being lost to modernization. Building good bomas and conscientiously tending livestock require time and effort at a time when poison is readily available and spearing lions is the only traditional test of manhood left for young warriors. As a cash economy has become increasingly relevant to rural Africans, they have lost their tolerance of predators and are likely to continue eliminating lions unless they bring in financial benefits that outweigh costs.

Comment [HK2]: I question the tone of this statement

In many areas, tourism ventures are encouraged with unrealistic promises of wealth creation and/or employment in areas where tourism is unlikely to be sustainable or without sufficient investment in local skills development (Walpole and Thouless, 2005, Hemson, 2003). In these circumstances (which might easily be extended to hunting) the potential for wealth generation should not be overstated when setting up a new venture. Having encouraged a community to view lions and wildlife as their own private economic resource, conserving the local lion population might no longer make sense should the economy change (e.g. Zimbabwe) or the venture fail to live up to economic expectations of a growing population. That's not to say that encouraging sport hunting and tourism is bad, but an enormous amount of work remains to identify the components of a successful venture.

Lion Attacks on Humans

Although depredation of livestock may be the most widespread form of human-lion conflict in Africa, lion attacks on humans are not uncommon. This form of conflict poses unique challenges for lion conservation that must balance the needs of local people and the long-term viability of lion populations. Historic man-eating lion outbreaks like the "Man Eaters of Tsavo" have become modern-day legends and such cases of sustained localized outbreaks have occurred throughout Africa for millennia. One of the worst recorded cases occurred in the Njombe district of southern Tanzania in the 1930s, when lions killed about 1,500 people in a 150 square mile area over a 15 yr period (Peterhans & Gnoske 2001). Perhaps equally shocking is the level of attacks currently occurring in southeastern Tanzania. Since 1990, lions have killed close to 600 people and injured at least another 300. This number represents a four-fold increase in attacks in the last 15 years (Packer *et al.* 2005). These attacks are not one large outbreak attributed to a single lion or lion pride but are due to multiple isolated outbreaks geographically dispersed throughout the country and attributed to dozens (if not hundreds) of lions.

A number of factors are believed to contribute to man-eating outbreaks by lions, including passive provisioning with human remains, attraction to livestock, lion social traditions and behavior, poor health or injury, vegetation and habitat characteristics, climate and seasonality, and prey depletion (Peterhans & Gnoske 2001). It is likely that for both historic and current outbreaks a number of these factors are working simultaneously. Passive provisioning of lions with human remains may have played an important role in historic man-eating outbreaks. Human remains are likely to have been left unburied as part of the brutal history of the slave- and caravan-trading routes, as well as from disease epidemics and human warfare. Provided with this easy source of food, lions may have developed a taste for human flesh, potentially leading them to seek live human prey. Lions may also be attracted to humans due to their possession of livestock. If a lion kills a person while raiding livestock, it might subsequently begin preying on people (Peterhans & Gnoske 2001).

Lions may pass on the behavior of attacking people to their offspring. This is especially likely during long outbreak periods where multiple generations of lions are involved. In addition to learned behavior, lion attacks on humans may be spurred by competition between prides and by expulsion of juveniles from their natal prides. The stress suffered by a small pride living next to a large pride was implicated in a 1991 outbreak of man-eating in Zambia (Yamazaki & Bwalya 1999). Data collected outside Tsavo National Park in Kenya indicates that most problem lions were less than five years old and had most likely left the park because they were unable to establish themselves in existing territories. By leaving the park, these lions were more likely to encounter people and attack livestock or humans (Patterson *et al.* 2003).

It is possible that some outbreaks of man-eating started because lions tend to attack prey that is either ill or behaving abnormally. In some cases, inebriated men became targets due to their abnormal behavior after leaving a bar late at night (Schaller 1972); this was also the circumstance of Kenya's only recorded case of human predation in recent years. Another important factor may be the health and age of the lions themselves. Malnourished, wounded, or aged lions that have difficulty catching their normal prey may start capturing humans. Historic man-eating incidents have been attributed to lions with tooth ailments, damaged limbs, and porcupine quills embedded in their paws (Peterhans & Gnoske 2001, Patterson *et al.* 2003).

Environmental factors such as vegetation, habitat, climate, seasonality, and prey availability may all affect the likelihood of lions attacking people. Vegetation cover and habitat can have an impact on a lion's ability to capture prey. In some cases, a certain amount of cover is crucial for hunting success, but in

others, cover type may actually hinder hunting abilities. Dense cover near human settlement may provide areas for lions to hide undetected and stalk people from close distances without being noticed. But in tall grasses that rustle easily, lions may sometimes find it harder to catch their natural prey, making them more likely to turn to humans as food (Peterhans & Gnoske 2001). Floods may create barriers to movement and separate lions from their natural prey. Prey depletion due to disease, drought, habitat degradation, and over-hunting have all been implicated in man-eating outbreaks. In Njombe, where as many as 1,500 people were killed over a 15 year period, the outbreak was attributed to the establishment of a large game-free zone by the British to prevent the spread of rinderpest to livestock (Peterhans & Gnoske 2001).

Environmental and behavioral factors are likely to interact to create man-eating outbreaks and to vary across man-eating incidents and geographical locations. In southeastern Tanzania, prey availability, habitat type, seasonality, and human activities all contribute to chronic man-eating outbreaks. Attacks are highest in districts with the lowest abundance of natural prey and the highest abundance of bush pigs (Packer *et al.* 2005). Subsistence hunting and habitat degradation due to fire and agriculture may have depleted the mid-sized antelopes in these areas. Bush pigs, unlike other mid-sized prey, flourish in human dominated agricultural areas, as they are such adept crop raiders. In addition, because southeastern Tanzania is predominantly Muslim, bush pigs are not common targets of subsistence hunting. The most common context of attacks is when people are tending crops (27% of all cases), and almost 40% of attacks occur during harvest time (March-May), which coincides with the wet season (Packer *et al.* 2005). During this time, people sleep in their fields in makeshift huts to protect their crops from bush pigs. The compounding factors of prey dispersal during the wet season, bush pig attraction to human-dominated areas, and people being especially vulnerable in makeshift huts, makes tending and protecting crops the most common context for lion attacks. Other activities associated with a high risk of attack are walking alone in the early morning and evening hours when lions are active, going to the outhouse at night, and participating in retaliatory lion hunts (Packer *et al.* 2005).

Aside from being a major threat to people, man-eating outbreaks also cause a major threat to long-term lion population viability. People who fear for their lives and safety are, at best, unlikely to support conservation effort and, at worst, likely to retaliate by killing any lions found near human settlements. Poisoning of bush pig carcasses is not uncommon and in one case, the body of a human victim was dosed with poison to kill the offending lions. District game officers in Tanzania kill numerous lions each year in retaliation for attacks. Since 1980, game officers in Tunduru district killed 83 lions; almost half of these were killed after a major man-eating outbreak in the late 1980s. In Rufiji district, 94 lions were killed by game officers and another 34 were injured between 1980 and 1990 alone. Although no one would

question the killing of lions that put people's lives in danger, it is evident that retaliatory killing of lions poses a substantial threat to lion populations in southeastern Tanzania.

Solutions

Solutions to the current man-eating lion problem in southeastern Tanzania must balance the needs and safety of local communities with lion conservation efforts. The most promising solutions to such conflict may involve assisting local residents in making their day-to-day activities safer. In areas where bush pigs are a major problem, bush pig control would reduce the need for people to sleep in agricultural fields and limit contact between lions and humans. Additional measures would include encouraging people to avoid walking long distances during high-risk times of day and building visual barriers to surround their homes, outdoor toilets, and cooking areas. People are also drawn to wildlife areas to collect water and firewood, so providing water sources in the village center and developing alternatives to firewood collection on foot would also limit human contact with lions. In addition, improving the speed and thoroughness of the responses by district game officers would greatly reduce the likelihood that the same lion or lions would kill numerous people before being caught and killed. Lastly, in order to maintain viable lion populations that do not pose a constant threat to neighboring villages, efforts to conserve habitat and increase mid-sized lion prey are critical. Unless lions have alternative sources of food, they will continue to turn towards humans as an easy source of prey. It is only with a combined effort that takes into account improving human safety, rapid response to attacks, and habitat health that man-eating outbreaks in southeastern Tanzania will be prevented. Without such effort, there is a risk of complete extermination of lions from these areas. In Njombe, home to the most deadly man-eating outbreak in history, lion attacks no longer occur because lions have been eradicated from the area. With Tanzania hosting almost 50% of Africa's lion population, man-eating outbreaks threaten not only human lives and livelihoods, but also threaten lion survival throughout Africa.

Conclusions

Large carnivores are among the most problematical animals to conserve because their feeding habits inevitably bring them into conflict with humans. At the same time, their wide ranging movements and need for substantial prey populations require very large areas, and thus only the biggest protected or well-managed landscapes currently provide relative long term security for viable populations; only six such areas currently exist in Africa. Elsewhere, we will either learn to live with lions or we will lose them. We have shown that ancient livestock husbandry methods effectively protect livestock from lions, and data on the socioeconomic and ecological circumstances that lead to man-eating gives us confidence that proper management can minimize attacks on people. However, spears, bullets and poison are always cheaper and easier solutions than managing livestock, lions or growing rural human populations. Thus, rural people must perceive lions and other wildlife as valuable commodities if they are to accept the

burden of living with animals: the benefits of wildlife must outweigh the costs. Effective lion conservation must combine effective management of risks with development of viable wildlife-based economies that improve the lives of rural Africans. Traditional peoples and wildlife managers already have most of the techniques necessary to manage depredation, but the greater challenge of managing ecologically sustainable rural development lies in the realm of policy, social science and politics.

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