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Evaluation of a compensation scheme to bring about pastoralist tolerance of lions

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ABSTRACT

Lions (*Panthera leo*) are in decline throughout most of their range due to human persecution, largely provoked by depredation on livestock, and there is debate as to the usefulness of financial instruments to mitigate this conflict. Intending to reduce local lion-killing, the Mbirikani Predator Compensation Fund compensates members of Mbirikani Group Ranch for livestock depredation at a flat rate (close to average market value), after the kill has been verified and with penalties imposed for poor husbandry. Despite penalizing claimants, 55% of claims arose because livestock were lost in the bush. Between 1st April 2003 and 31st December 2006, 754 cattle, 80 donkeys and 1844 sheep/goats were killed (2.31% of the total livestock herd each year). Forty-three percent of kills were ascribed to spotted hyaenas (*Crocuta crocuta*); leopards (*Panthera pardus*) and cheetahs (*Acinonyx jubatus*) were blamed for 37% of cases, lions 7%, jackals (*Canis mesomelas*) 7% and buffalo (*Syncerus caffer*) and elephants (*Loxodonta africana*) together 6%. Significantly more attacks took place during months of lower rainfall but the rate of attacks was not related to the density of livestock on the ranch, or the ratio of wild herbivores to domestic stock. There was no correlation between local market prices and the number of claims per month. Despite compensation, at least one lion per year was killed in 2004, 2005 and 2006. We describe some features of large carnivore depredation in the study area and suggest that regional recovery of the lion population may require compensation on a wider scale.

1. Introduction

1.1. *Depredation as a driver of persecution of large carnivores*

Studies on different continents under diverse social and economic circumstances have concluded that depredation on livestock is an important cause of human intolerance for large carnivores, frequently leading to their extirpation. From the Mongolian steppe to the ranches of Montana, the link between stock losses and carnivore persecution has prompted livestock compensation schemes with the general intention of mitigating this conflict (for a review see Montag and Patterson, 2001). Stock losses to carnivores can be particularly dam-

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aging on communal lands in poor countries, many of which support important wildlife assemblages. Kenya, Botswana, Malawi and Zimbabwe are examples of the few African countries that have implemented state-run compensation schemes in the last quarter of a century. Consequently, various smaller-scale "direct incentive" schemes have been explored as a means of increasing tolerance of large carnivores. Despite the obvious importance of the topic, few African compensation schemes have been rigorously analyzed, and their effectiveness in reducing local efforts to eradicate problematic wildlife is largely unknown (Nyhus et al., 2005).

Adjoining the Serengeti–Mara ecosystem and the Maasai Steppe, the Amboseli–Tsavo ecosystem hosts part of the largest remaining free-ranging, contiguous lion (*Panthera leo*) populations (IUCN, 2006). Together these areas cover 202,490 km^2 and are estimated to hold at least 4500 individuals, representing as much as a fifth of Africa's lions (Bauer and Van Der Merwe, 2004). The corridor of unprotected land linking Tsavo and Amboseli National Parks is crucial to lion conservation in the region as it serves as a wet season dispersal area for the wildlife population of Amboseli NP (Groom R., unpublished data) Despite being one of Kenya's smallest parks (392 km^2), Amboseli is an extremely popular tourist destination and generates major revenue from the tourism industry, while Tsavo (21,812 km^2) comprises the largest protected wildlife area in Kenya. This ecosystem is important both for global lion conservation and East African wildlife conservation generally.

1.2. *Lion extirpation in the Amboseli–Tsavo ecosystem and the establishment of MPCF*

Lions are killed in the Amboseli–Tsavo ecosystem in retaliation after killing livestock, sometimes in defense of livestock, and sometimes as part of a rite of passage (manhood) ritual, known as Olomayio (Hazzah, 2006). Between 1991 and 1994 lions were extirpated from Amboseli National Park, mainly by poisoning (Chardonnet, 2002). In 1994 two lions appeared in the east of the park. These lions successfully recolonized the park and Watts and Holekamp (pers. comm.) estimated that in November 2005, 51 lions were using Amboseli NP. Surrounding communal lands were the source of lions to repopulate Amboseli.

In the early 2000s, conservationists and tourism operators documented unusually high numbers of lions being speared and poisoned on group ranches (communally owned traditional Maasai grazing lands) around Amboseli. The Amboseli–Tsavo Game Scouts Association, a privately-organized paramilitary law enforcement group which collaborates with the Kenya Wildlife Service (the governmental wildlife protection body), began recording the circumstances of these killings in 2001, leading in turn to the establishment of the Mbirikani Predator Compensation Fund (MPCF) by Richard Bonham and Thomas Hill of the Maasailand Preservation Trust (MPT). The MPCF is funded by private donations and creates direct incentives to Mbirikani Group Ranch (MGR) residents to forego retaliatory killing of predators. Here we report on the first four years of the MPCF.

2. Methods

2.1. *Study area*

Mbirikani Group Ranch (1229 km^2) is part of the Amboseli–Tsavo ecosystem in southern Kenya's Kajiado District, with central coordinates 37.59°E; 2.51°S (Fig. 1). The eastern boundary of the ranch is mountainous at an elevation of about 1900 m and adjoins Chyulu Hills National Park, whereas the western boundary of the ranch, about 6 km from Amboseli National Park, forms part of the low-lying Amboseli basin. Approximately 8.5% of the ranch is open grassland and the Mbirikani short grass plains are a critically important dispersal area for wildebeest (*Connochaetes taurinus*) and zebra (*Equus burchelli*) from Amboseli during the rains (Western, 1973). This herbivore migration almost doubles the biomass of potential prey available to carnivores. For example, in the 2005 wet season there were estimated to be 9000 wildebeest and 8000 zebra on MGR as compared with <5000 of each in the 2005 dry season (Groom R., unpublished data) Other potential prey species such as eland (*Taurotragus oryx*), hartebeest (*Alcelaphus Buselaphus*), fringe-eared oryx (*Oryx gazella callotis*), lesser kudu (*Tragelaphus imberbis*) and Maasai giraffe (*Giraffa camelopardalis tippelskirchi*) occur at lower densities. The rainfall is bi-modal, with rains falling mainly during March to May and October to December. Annual rainfall of the Amboseli basin varies between 132 and 553 mm (Altmann et al., 2002). Mbirikani Group Ranch is governed by a committee whose members are elected every few years by registered members of the ranch and which manages the ranch and represents the members in dealings with government, NGO's and businesses.

Membership (adult heads of households) of Mbirikani increased from 922 members in 1981 (Campbell et al., 2005) to 4650 members (c. 10000 people) in 2006 (Groom, 2007). The dominant livelihood is semi-nomadic pastoralism and the majority of household income is derived from livestock sales. By contrast, income from wildlife (tourism and contributions from the Kenya Wildlife Service) amounted to only 3% of an average household's income (Groom, 2007). MPT has run a predator compensation scheme since 2003, operating under an annually-renewable contract negotiated between the Group Ranch Committee and MPCF (Supplementary material).

2.2. *Data collection*

RJG obtained density estimates of livestock and wildlife through monthly ground counts using strip and point transects (Groom, 2007). In each month (December 2004–November 2005 inclusive), a new set of 22 strip transects of 4 km in length were laid out in a stratified random sampling design according to habitat (Krebs, 1999) and further stratified by wildlife abundance. Strip width varied according to visibility. In one habitat, where driving transects was precluded by the terrain, 25 randomly located point transects were monitored monthly, accessed by bicycle or foot. For both transect types, all animals falling within the set area were counted (distances were checked where necessary using a Yardage Pro 500 rangefinder). A comparative test of the two techniques

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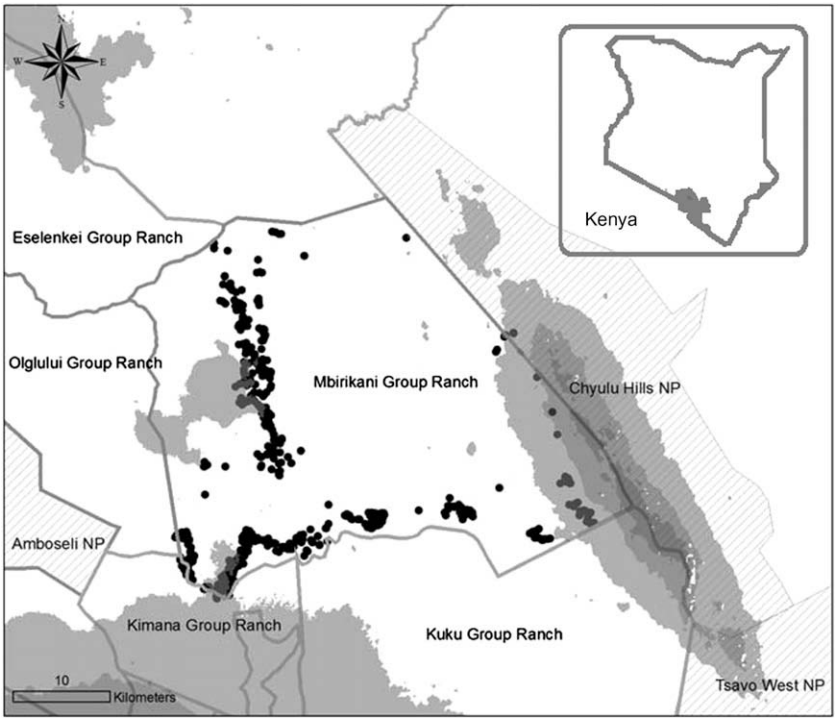

Fig. 1 – Map of Mbirikani Group Ranch and surrounds. Permanent bomas are shown as black circles and darker grey shading represents areas of higher elevation. Inset shows the location of the study area within Kenya.

showed no significant differences in density estimates (Groom, 2007).

For some analyses, data were grouped into seasons. Months were assigned a season (wet, dry or very dry) on the basis of measures of grass biomass per unit area and percentage green vegetation cover (see Groom, 2007).

Data on livestock depredation was provided by MPCF. One of the authors (SDM) carried out 4.8% of the verifications (77 cases) and regularly cross-checked the claim data from verification officers for accuracy. For the purposes of this analysis, leopard and cheetah attacks have been grouped together as most Maasai do not distinguish them as separate species. Average monthly livestock prices from the nearest market town (Emali) were obtained from the Livestock Information Network System (LINKS, 2007).

2.3. *Lion population data*

Between May 2004 and August 2006 SDM fitted four adult female and two male lions with VHF radio-collars (Telonics, model Cmm-410). An additional male and female were fitted with GPS, download-on-demand collars (Telonics Model TGW-3690 and TGW-3590). All animal handling was approved by University of California, Berkeley, Animal Care and Use Protocol R191. The radio-collared individuals and any companions were located from the ground and air using a Communications Specialist R-1000 receiver, a minimum of once per week whenever possible. Positions of collared animals and their companions were recorded using a Garmin GPS III+. Sightings of undocumented (or uncollared) lions were reported to SDM by local tourism operators and Game Scouts and were followed up whenever possible. The minimum number of positions recorded for a collared lion in the study was 24, while the maximum was 4029. The average number of fixes taken for radio-collared animals in the study was 74. Collared lion recordings covered 2004, 2005 and 2006 except for one lion that was collared in 2005 and two collared lions which died before data could be collected on them in 2006. The lion population of Mbirikani has been estimated through complete counts monthly since March 2004 by SDM, based on direct observations of lions located either by radio-tracking or following up on reported signs and sightings. Records of lion mortality and distribution were collated from MGR residents and the Game Scouts.

3. Results

3.1. *The structure and functioning of the Mbirikani Predator Compensation Fund (MPCF)*

The MPCF was established in early 2003, administered through the Maasailand Preservation Trust, a human development and wildlife conservation NGO based on Mbirikani ranch. The terms and conditions of MPCF were negotiated by the Group Ranch Committee and the administrators of the fund, formalized in an agreement that can be re-negotiated annually. All operational costs and 70% of the livestock payments are borne by MPCF, while the group ranch covers 30% of the livestock payments, this money being earned from selling of raw materials, land rents and conservation fees. The first claim was accepted on 1 April 2003 and thereafter claims were accepted for 1094 days through 2006. During this time the program was suspended on three occasions: from 28th June 2003 to 21st January 2004 in response to a lack of

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co-operation from the community in identifying a person who poisoned several carnivores and attempted fraud by the Group Ranch Committee as documented by MPT; from 7th April 2005 to 22nd June 2005 due to lack of agreement on a proposed decrease in payments for stray livestock claims and from 4th October to 12th of October 2005 due to the failure of the Committee to hand over a fine for the killing of two lions on the ranch.

A diagram of the structure of the MPCF is given in Fig. 2. Only registered members of Mbirikani Group Ranch are eligible. Claims are accepted if the carcass of the livestock is on or within 1.5 km of the ranch. Claims must be reported within 24 h of the animal being killed and claimants are asked to protect the evidence (carcass, spoor, drag marks). If the verification officer is satisfied that the case is genuine he issues a promissory note to the claimant. If the verification officer finds that a case does not conform to the rules of the agreement, or that the claimant deliberately misled MPCF, he has the option of issuing a "false claim" with an accompanying fine, or he can just choose not to award the claim. Promissory notes are redeemed on the next payout day, which occur every second month.

According to the agreement, if a lion, cheetah, leopard, spotted hyaena, striped hyaena (*Hyaena hyaena*), elephant or buffalo is killed illegally, those responsible are fined and compensation is withheld from all the members of the zone in which the animal was killed, for the two-month period in which the killing took place. Data on fines actually collected for predator killing or false claims were not available. On at least one occasion three people who participated in a lion-killing paid fines.

If a claimant is unhappy with the verification he/she can make a complaint to an Advisory Committee which comprises one elected elder from each zone and two women who represent the women of the ranch. On payout day, this committee arbitrates contentious cases and advises MPCF whether the claimants need to have their claims revised.

MPCF and the ranch community stipulate that cattle are valued at 13,500 Kenya Shillings; US$192.86 at the February 2007 exchange rate of Ksh70=US$1. Goats and sheep were valued at $28.57 (2000 Ksh) and donkeys at $85.71 (6000 Ksh). Kills attributed to hyaenas were paid out 50% of the values above. Penalties are imposed to encourage people to practice good livestock husbandry, i.e. to ensure that animals don't

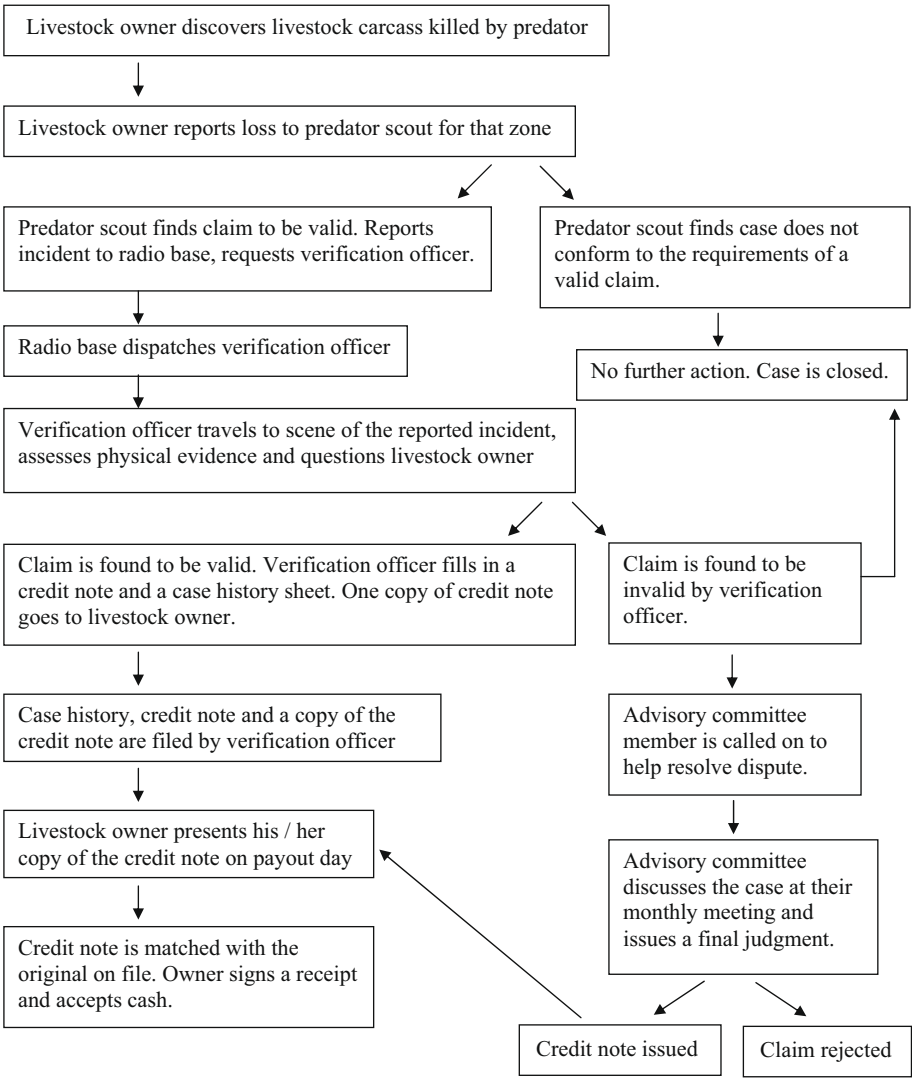

Fig. 2 – A flow diagram showing the structure of the Mbirikani Predator Compensation Fund administration.

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stray and are kept every night in a secure predator-proof boma (corral). The verification officer judges whether to apply a penalty while at the site of the kill. If no negligence was found, the claimant receives the full value specified by MPCF. If the livestock are taken from a poorly constructed boma (defined as less than 4 feet high) then the claimant receives 30% of the valuation. If the owner had let the animal stray, he/she received 50% of the MPCF value of the animal.

In the initial negotiations with community leaders, MPT proposed that claims for animals killed while "stray" (left outside of bomas overnight) should not be accepted at all. This was rejected by the ranch members, who said that they would continue killing predators in the absence of payment for strays.

3.2. *Attributes of depredation*

Over the 1094 days that MPCF was accepting claims, 1694 claims were submitted covering 754 cattle, 80 donkeys and 1844 sheep/goats. Eight hundred and fifteen ranch members (18%) have lodged claims. At least one claim was lodged on 72% of days (789 days), ranging between one claim per day to a maximum of 11 on a single day. The average number of claims per month was 23 in 2003; 50 in 2004; 50 in 2005 and 58 in 2006.

Forty-three percent of kills were ascribed to spotted hyaenas, leopards/cheetahs were blamed for 37% of the cases, lions 7%, jackals 7% and buffalo and elephants together 6%. In 2006 cheetahs, leopards and jackals appear to have contributed more to the number of claims than in previous years (Fig. 3). This increase may reflect a cheetah population that is growing in response to a reduction in cheetah killing by humans due to the compensation agreement and/or the drop in lions and hyaena numbers (Kelly and Durant, 2000).

The average annual percentage of the total livestock herd lost to depredation on the ranch was 2.31%. Hyaenas killed 1.43% of the herd, cheetah/leopard 0.59%, lion 0.10%, jackal 0.17% and "other" (elephant, buffalo and probably occasionally domestic dogs) 0.02%. Given average market prices, this amounted to an average ranch-wide loss of $69,193 per year.

3.3. *MPCF payouts*

Fig. 4 summarizes the payments made by MPCF in relation to the average market value of the livestock reported killed. Actual payouts are lower than the market values due to the application of penalties for poor husbandry (Table 1).

There was no correlation between the average market price of cattle and the number of claims per month ($R = 0.284$, $P = 0.269$, $N = 17$), suggesting that people were not intentionally bringing about depredation so as to take advantage of favorable market conditions. The average price paid out by MPCF for cattle killed by carnivores (single-cow claims) ranged between 27% and 94% of the average market price, Fig. 5. The average amounts represented in Fig. 5 include claims that have been penalized.

3.4. *Penalties*

Table 1 summarizes the proportion of the cases that were assigned to each penalty category by all the verification officers. A chi-square test was carried out to assess the consistency between the judgments of different verification officers, considering only those who had adjudicated at least 10 claims. There was no significant difference in the number of penalties awarded by the verification officers ($\chi^2_3 = 7.167$; $P = 0.067$; $N = 1185$ cases). However SDM ($N = 77$ cases) awarded penalties in a significantly higher proportion of cases than did the three Maasai officers ($\chi^2_1 = 4.633$; $P = 0.031$). This could have been due either to collusion between claimants and verification officers, or miscommunication between claimants and SDM (through the translation process) resulting in mistaken assignation of penalties to cases.

The frequency of stray cases was low in 2003 (37%), but has been higher, and more consistent, thereafter (53% in 2004, 66% in 2005 and 54% in 2006). The low frequency in 2003

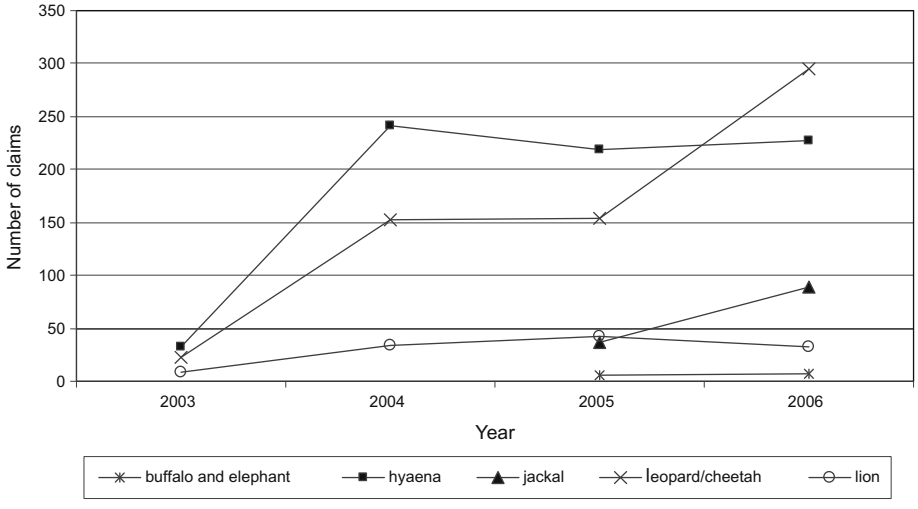

Fig. 3 – Number of claims ascribed to different predators, 2003–2006. The increase in numbers ascribed to leopards/cheetahs may be function of release after decline in larger predators.

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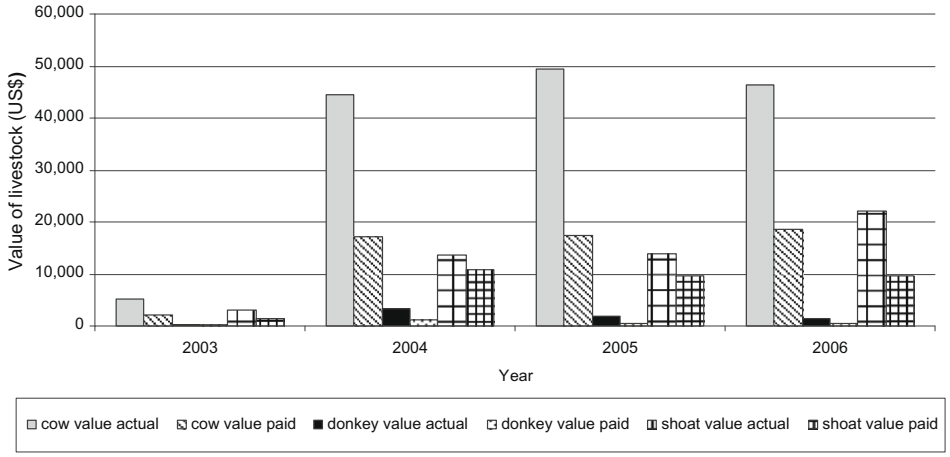

Fig. 4 – Actual market value of all livestock claimed for (value actual) and amount paid out by MPCF for claimed livestock (value paid). Note that the MPCF was not accepting claims for part of 2003 and 2005. (Shoat = sheep and goats).

Table 1 – Penalties assigned to livestock claims made to MPCF. The "unspecified" category represents cases where the case penalty status was not specified.

Penalty	Cases where penalty awarded
Bad boma	39 (2%)
Unspecified	56 (3%)
No penalty	671 (40%)
Stray	928 (55%)
Total	1694 (100%)

might have been due to a poor understanding of the classification of the penalty clauses by verification officers.

3.5. *The effect of rainfall and season*

A significantly higher percentage of claims were classified as stray during the wet season (66%) and times of drought (71%), as compared with the dry season (55%), ($H_2 = 6.74$; $P = 0.034$). However, post-hoc testing showed no evidence of a difference in the medians of stock killed during wet and dry seasons ($H_1 = 3.29$; $P = 0.070$). The total number of claims each month was significantly higher when rainfall was lower (Pearson's $R = -0.387$; $P = 0.042$).

3.6. *The effect of the proportion of wild to domestic prey*

There was no correlation between the density of livestock on the ranch and the number of attacks per month ($t = 0.682$; $P = 0.514$; $N = 10$, Fig. 6). Nor was number of attacks per month a function of the ratio of wild herbivores to domestic stock ($t = 0.476$; $P = 0.647$; $N = 10$, Fig. 7), or of the actual wild prey density.

3.7. *Lion demography*

We recorded the lion population of Mbirikani every month in 2004, 2005 and 2006. The maximum number of individuals recorded was 15 in 2004, 17 in 2005 and 18 in 2006. However, the influx of lions from Amboseli NP during the wet season can boost lion numbers temporarily, and average monthly numbers were lower: 14 in 2004, 14 in 2005 and 12 in 2006. No

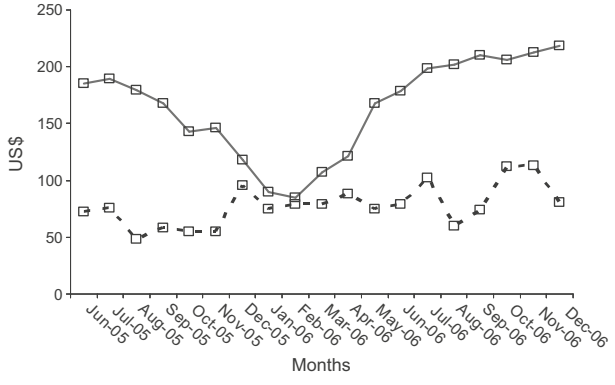

Fig. 5 – Average monthly market prices for cattle (solid line) [from LINKS (2007)] and the average price paid out by MPCF for single-cow claims (dashed line) from June 2005 to December 2006.

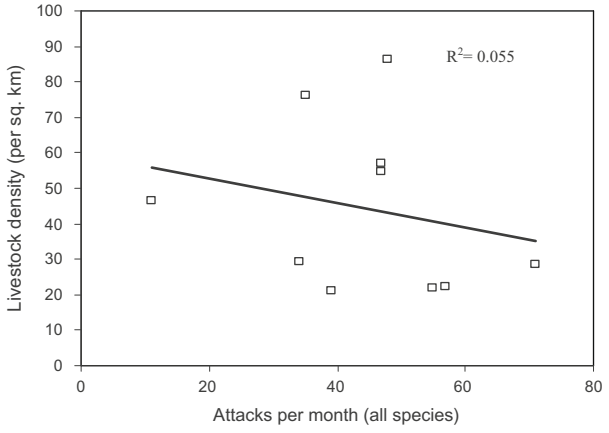

Fig. 6 – Domestic livestock density per square km versus number of predator attacks per month.

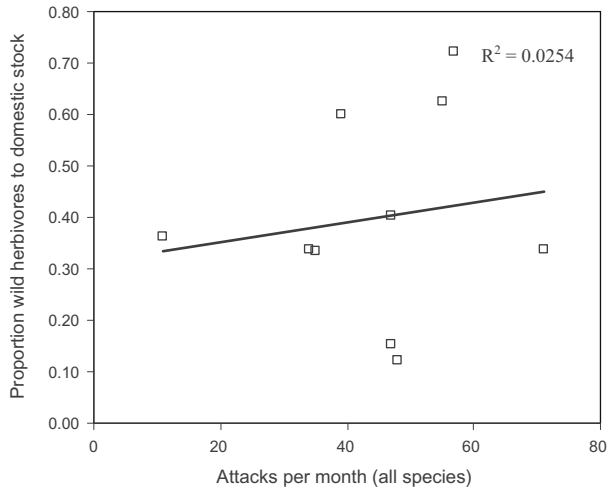

Fig. 7 – Proportion of wild herbivores to domestic stock versus attacks per month.

measurement of lion density on other ranches was possible, though this may have varied considerably.

Records of lion-killing on Mbirikani and neighboring group ranches are shown in Table 2. Reporting of lion-killing may have been more thorough on Mbirikani ranch as this has the highest number of game scouts employed to monitor illegal wildlife killing. Five lions were killed on Mbirikani between 2004 and 2006, four of them hunted and speared and one killed in a snare set for large herbivores. The killing of two lions normally resident on MGR on a neighboring ranch without compensation and the killing of a pride male and two females with dependent cubs on MGR likely accounts for the failure of the lion population on the ranch to increase.

3.8. *Cost of conserving lions on Mbirikani Group Ranch*

Under the current system, the mean annual cost of conserving a lion on Mbirikani averages over $3400 for compensation, plus another $2800 for the costs of lion population monitoring (Table 3). However, because MPCF payments include the money paid for kills by other carnivores (a necessary inclusion in the scheme to protect the lions), the cost per includes an additional level of protection for the other carnivores.

4. Discussion

Compensation is widely used in the Americas and Europe to mitigate conflict (Montag and Patterson, 2001) but has also been widely criticized. Bulte and Rondeau (2005) describe "moral hazard", where the incentive scheme encourages behavior detrimental to its objectives, such as lax livestock husbandry or poor defense of livestock. Some argue that people intentionally abuse compensation schemes to their benefit (Nyhus et al., 2003). Others compare the costs of compensation with other (less costly) conservation interventions (see Nyhus et al., 2005) or describe the difficulty of reconciling the divergent interests of livestock farmers with carnivore conservationists. Treves and Karanth (2003) condense many of the difficulties of conserving predators into a

Table 2 – Number of lion-killing incidents recorded (and lions killed) per year from 2001 to 2006. Total number of lion-killing incidents per km² over all years is shown. These figures represent a minimum, as some incidents probably went unrecorded.

Group Ranch	Total lion-killing incidents (and number of lions killed)						Lion-killing incidents per km²
	2001–02	2003	2004	2005	2006	Total 2003–2006	All years
Eselenkei	–	0	1 (4)	0	2 (8)	3 (12)	0.0038
Kimana	–	1 (1)	0	0	0	1 (1)	0.0039
Kuku	–	0	6 (9)	6 (6)	2 (2)	14 (17)	0.0143
Mbirikani	13 (24)	–	1 (1)	1 (2)	2 (2)	4 (5)	0.0030
Olgulului	–	6 (8)	6 (6)	7 (9)	13 (18)	32 (41)	0.0200
Rombo	–	0	0	0	1 (2)	1 (2)	0.0025
Total	13 (24)	7 (9)	14 (20)	14 (17)	20 (32)	55 (78)	0.0103

– = Data not available.

Table 3 – A breakdown of the costs associated with the conservation of lions on Mbirikani Group Ranch (amounts shown are in US $).

Year	2004	2005	2006	Average
Number of lions on Mbirikani	14	14	12	13
Total MPCF compensation payments	29600	29806	39943	33116
MPCF staff wages	2660	5497	9111	5756
Other MPCF expenses	5329	5329	5329	5329
Scientific research and monitoring	31018	42251	36225	36498
Total expenses incurred by lions	68606	82882	90608	80699
Cost per lion on Mbirikani	**4900**	**5920**	**7551**	**6124**

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single statement, "Carnivore management is as much a political challenge as a scientific one". Financial sustainability of any direct incentive scheme is of utmost importance (Nyhus et al., 2005), especially if the motivation to conserve wildlife becomes purely financial, and withdrawal of the financial incentives can be detrimental to long-term conservation (Gadd, 2005; Macdonald, 2000).

4.1. *Fulfillment of MPCF objectives*

As stated by its founders, the primary objective of MPCF is to reverse the decline in lion numbers by increasing ranch members' tolerance of predators to prevent retaliatory lion-killing after depredation incidents. A secondary objective is to foster an improvement in livestock husbandry, so as to minimize carnivore-livestock conflict.

While the number of lions killed on Mbirikani was as high as 24 in 2001/2002 (Table 2), only one or two were killed annually in 2004, 2005 and 2006. There are several candidate explanations for this decline in killing, each of which may play a role. Firstly, it may be that MPCF has adequately alleviated peoples' financial loss and thus reduced their propensity to retaliate. Linked to this would be group ranch members refraining from killing lions due to the fear of sanctions from their immediate community (peer pressure), when compensation is withheld. Alternatively, people may have stopped killing lions for fear of subsequent arrest and prosecution. However, the decline in lion numbers might also be important here. Although we do not have data from before 2004, lion density is clearly lower than it had been prior to MPCF (R. Bonham, pers. comm.), i.e. there are simply fewer lions left to kill. In addition, the surviving lions spend the daytime hours in heavily overgrown lava beds that are nearly impenetrable by humans, making these lions very difficult to hunt. It is possible that some lion-killing goes unreported, but this is unlikely as most are collared which leads to their discovery (four out of six collared lions that were killed were reported as dead by game scouts, independent of the aid of telemetry). Further, many people believe either that the collar will report them if they kill the lion (Rodriguez, 2006) or that the research attention paid to the lions makes arrest more likely for killing one. Finally, lion-killing is a very public event (successful warriors roam among settlements singing of their victory), so the entire community soon knows (Hazzah, 2006). All of these factors may contribute to the lowered rate of killing on Mbirikani since the initiation of MPCF. Unfortunately, even though lion-killing has decreased on Mbirikani, there has been no recruitment of cubs and movement of Mbirikani lions onto surrounding ranches exposed them to pastoralists who did not benefit from compensation (Table 2).

The secondary objective of MPCF, improving livestock husbandry, has not been achieved. Negligent herding is the single largest cause of losses to predators, and penalties for poor herding have not reduced its impact from 2004 to 2006. Reasons for this are unclear.

4.2. *Legal sanctions against lion-killing, fines against false claims*

The killing of lions in Kenya is legal if the perpetrator can prove that it was in defense of life or property (Wildlife Act, 1989), including livestock. Between 2004 and 2006, despite four incidents of lion-killing on Mbirikani, not one person has been prosecuted for killing a lion, even though in some cases the culprits were known. Given the finding by Hazzah (2006) that fear of arrest was a strong deterrent to killing lions on Mbirikani, unprovoked lion-killing might be reduced by more effective law enforcement and rigorous prosecution.

4.3. *Corruption and false incentives*

Although the attribution of penalties to cases varied significantly between Maasai verification officers and one of the authors (SDM), it is unlikely that this was due to intentional manipulation of the rules as random checks (minimum of 2 per month during 2006) on verifications were carried out by MPCF supervisors. No indication of misconduct by verification officers was found. SDM has no kinship or clan ties with claimants, and may have been less likely to compromise in adjudications; Maa-speaking verification officers might elucidate the facts of a case more easily, and could avoid over-penalizing cases through miscommunication.

Bulte and Rondeau (2005) hypothesize that compensation can lead to "excessive damages" as people put their livestock (especially sick animals) into situations where they will be killed in order to qualify for compensation. However, despite MPCF paying close to market price in February 2006, there was no corresponding increase in claims submitted, suggesting that compensation did not produce perverse incentives for poor husbandry.

4.4. *Patterns of depredation*

The average annual proportion of the ranch's herd killed by large carnivores on Mbirikani (2.31%) is similar to the value of 2.4% recorded by Patterson et al. (2004) for ranches adjacent to the nearby Tsavo National Park. If anything, the figure for Mbirikani may be an underestimate, since total livestock numbers are boosted by cattle of non-ranch members coming onto Mbirikani for grazing at certain times of year. Moreover, people may have livestock killed by carnivores but fail to find the carcass in time to report it to MPCF, or be unable to leave the rest of the herd to seek out a verification officer after a depredation event.

The weakly significant negative correlation of rainfall with rate of claims is at odds with depredation patterns described in the neighboring Tsavo area (Patterson et al., 2004), where the positive correlation of depredation with rainfall may reflect the lions increased dependence on livestock due to difficulty in finding dispersed wild prey during the wet season. Mbirikani on the other hand, is a dispersal area for Amboseli wildlife, and wild prey increase on Mbirikani during the rains, possibly reducing pressure on domestic stock. Alternatively, it is possible that people lose livestock to carnivores with equal frequency in all seasons, but fewer carcasses are found when grass is longer in the wet seasons and are thus not submitted to MPCF.

The distinguishing feature of depredation in this area is the high percentage of animals that are killed while

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unattended (stray). BurnSilver, Boone & Galvin (2003) suggested that long daily grazing distances and poor body condition during very dry months, may expose livestock to greater risk of straying. Many of the herders on Mbirikani are young boys and/or only looking after the livestock as part of a family obligation, rather than as a wage-earning job. Stronger incentives and the employment of adults might improve herding.

The fact that hyaenas were responsible for 43% of livestock depredation is consistent with the findings of Kolowski and Holekamp (2006, unpublished data), working outside the Masai Mara National Reserve who found hyaenas contributed to 53% of depredation cases, and lions only 15%. However on the commercial ranches of Laikipia District lions cause most losses and poor herding is rare: stock are rarely left out at night where they are vulnerable to hyaenas (Frank, 1998).

4.5. *Potential modifications to MPCF*

An obvious solution to the high rate of stray claims is to cease paying for them, thereby removing the subsidy for poor livestock husbandry. In practice this modification of MPCF may not be feasible, as ranch members threaten they would respond by killing all carnivores (very effective poison is readily available). Alternatively, low wages in Kenya might make it economical for MPCF to pay professional livestock herders in areas, or with herds, that have a high prevalence of stray livestock depredation. Another approach might be a cash reward paid to livestock owners for good husbandry. For example, Mishra et al. (2003) describe a "livestock insurance program" in the Spiti valley, India that provides cash rewards twice per year for those who have the fewest livestock predation cases. Additionally, disincentives might be added to the compensation agreement to forestall livestock losses, such as paying claimants only if their herders are above a certain age or competency level.

Should predator populations begin to recover in the absence of improved husbandry, it is likely that the rate of depredation will increase. Further, given the present low predator densities, only a small percentage of each carcass is consumed, and there is usually a substantial amount of evidence on which a claim can be based. An increased predator population might reduce the physical evidence in some cases. Thus, it is important to reduce the availability of stray livestock before predator recovery occurs. Higher populations of carnivores might also lead to an increase in nocturnal attacks on bomas, necessitating improved standards of boma construction. In short, it is important that the MPCF is dynamic, the rules adapting to changing circumstances brought about by the scheme itself.

MPCF has recently (2008) been greatly expanded to include Olglului Group Ranch, bordering Mbirikani and Amboseli National Park, and a project modeled on MPCF has been established by the Masailand Wilderness Conservation Trust on Kuku Group Ranch to the south. This creates an area of 4000 km^2 in which people should have strong financial incentives not to kill lions. Some individual predators will inevitably develop the habit of taking livestock and need to be removed (Woodroffe and Frank, 2005), but traditional livestock husbandry can minimize losses of both livestock and predators (Ogada et al, 2003).

5. Conclusion

Between 2001 and 2006 there has been a reduction in the number of lions killed on Mbirikani Group Ranch, at least in part as a result of the MPCF being in place. This success has to be tempered with the knowledge that the current lion population is very low and that annual off-take from the Mbirikani lion population, often when they move onto neighboring properties, is still unsustainable (Table 2). The recent expansion of compensation programs to surrounding ranches is a critical test of this approach to lion conservation in Masailand. Lion populations that have been reduced to below carrying capacity are capable of rapid recovery; cub survival as high as 78.5% (Hunter et al., 2007) and annual growth rates of 30–80% have been reported for small populations free from human-caused mortality (Maddock et al, 1996; Kissui and Packer, 2004). If expanded compensation substantially reduces lion-killing in this ecosystem, measurable recovery of numbers may be expected within a few years.

Stronger disincentives may also be effective: more rigorous law enforcement and prosecution would probably reduce lion-killing (Hazzah, 2006) and would permit cessation of payments for stray livestock, as simply killing all predators would no longer be a viable response from the community. Interventions to reduce livestock losses could include improving husbandry to reduce stray livestock, increased vigilance during the dry times of year and financial incentives to reduce depredation. Some combination of additional measures, with adaptation of rules and procedures, may also be required should predator populations increase.

Losses to depredation can be substantial for individuals, and some people continue to dislike carnivores despite MPCF (Anonymi, pers. comm.). Despite this, there has been a decrease in the number of lions killed annually, and it is likely that MPCF has played a major role in the reduction. Expansion to the ecosystem level will be the critical test of compensation as a lion conservation tool in Masailand.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.biocon.2008.12.003.

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