A review of financial instruments to pay for predator conservation and encourage human–carnivore coexistence

Amy J. Dickman[1], Ewan A. Macdonald, and David W. Macdonald

The Recanati-Kaplan Centre, Wildlife Conservation Research Unit, Department of Zoology, University of Oxford, Oxford OX13 5QL, United Kingdom

Edited by Alexander J. Travis, Cornell University, Ithaca, NY, and accepted by the Editorial Board June 6, 2011 (received for review August 31, 2010)

One of the greatest challenges in biodiversity conservation today is how to facilitate protection of species that are highly valued at a global scale but have little or even negative value at a local scale. Imperiled species such as large predators can impose significant economic costs at a local level, often in poverty-stricken rural areas where households are least able to tolerate such costs, and impede efforts of local people, especially traditional pastoralists, to escape from poverty. Furthermore, the costs and benefits involved in predator conservation often include diverse dimensions, which are hard to quantify and nearly impossible to reconcile with one another. The best chance of effective conservation relies upon translating the global value of carnivores into tangible local benefits large enough to drive conservation "on the ground." Although human–carnivore coexistence involves significant noneconomic values, providing financial incentives to those affected negatively by carnivore presence is a common strategy for encouraging such coexistence, and this can also have important benefits in terms of reducing poverty. Here, we provide a critical overview of such financial instruments, which we term "payments to encourage coexistence"; assess the pitfalls and potentials of these methods, particularly compensation and insurance, revenue-sharing, and conservation payments; and discuss how existing strategies of payment to encourage coexistence could be combined to facilitate carnivore conservation and alleviate local poverty.

human-carnivore conflict | payments for ecosystem services

Conserving large carnivores is a pressing issue because of the striking declines in the geographic ranges and population sizes of these species, and also because of their arguable capacity as umbrella species for wider biodiversity. Resident populations of African wild dogs (*Lycaon pictus*) are thought to remain in only 7% of their original range, with cheetahs (*Acinonyx jubatus*) faring slightly worse, with resident populations in 6% of their original range (1). Even the iconic lion (*Panthera leo*) is thought to have declined by 30% to 50% during the past two decades (2), and similar dramatic declines have been experienced by many other large carnivores, including gray wolves (*Canis lupus*), tigers (*Panthera tigris*), and jaguars (*Panthera onca*) (3, 4). Such declines generate disproportionate amounts of attention, because these species are often imbued with high "existence value" by people in the developed world, who find predators alluring because of their power, mystique, beauty, and link to wild nature (5). This high existence value has generated a considerable market value associated with large carnivores at the global scale, manifesting itself predominantly through photographic tourism, trophy hunting, and zoos.

However, the high value ascribed to large carnivores by an international audience is rarely reflected at the local level, where local communities suffer substantial, diverse costs from their presence (6). These include direct economic losses from livestock depredation, which can be devastating, particularly in impoverished rural communities where livestock are a major source of income. Studies in Bhutan and Tanzania revealed that depredation cost villagers, on average, more than two thirds of their annual cash income (7, 8). Although depredation often causes less stock loss than factors such as disease (9), it is particularly problematic because it tends to be highly stochastic: one household may suffer a "surplus killing" event in which a carnivore kills many stock in one attack, whereas their neighbors suffer few or no losses. Such unpredictable, localized events are termed idiosyncratic shocks, and households may be able to withstand them thanks to informal community-based risk management mechanisms, which create a form of social insurance and enable assets to be transferred to an affected household. However, this situation is complicated further, as wealth is unequally distributed in many of the societies still coexisting with large carnivores. In such environments, poverty-stricken households are especially vulnerable to the impacts of depredation: they will not only suffer disproportionately from losing stock, but are also less likely to have built the social networks required to help buffer them against the impacts of such losses, driving them even further into poverty (10). This interaction is particularly important for pastoralists whose stock ownership falls below the threshold of 4.5 tropical livestock units (equivalent to 1,125 kg of livestock biomass) per capita, the level below which they are unlikely able to recover and reestablish their pastoralist lifestyles following stock losses (11).

Coexistence with large carnivores also entails significant indirect and opportunity costs. People invest in livestock herding, guarding, and predator control, the economic costs of which can be substantial (6, 12). The time required for livestock protection limits the amount of time available for other important activities such as attending school, and families affected severely by depredation are unable pay for costs such as school fees. This leads to a lack of investment in education and an intergenerational transmission of poverty, whereby children have limited alternative opportunities and remain ensnared within their families' poverty traps (10). Human fatalities caused by predators are another important cost in some areas (13), the consequences of which are made worse because the victims are often adult men, who are the key income generators for households. Furthermore, in many rural societies, livestock has cultural value exceeding its economic worth—the Maasai, for instance, value their cattle highly for social, political, religious, and cultural reasons, believing that they facilitate a direct link to their God, so cattle loss cannot easily be compensated through economic means alone (14).

In many of the priority areas for large carnivore conservation, the people who suffer most from predators are those who can least afford it—for instance, in

Author contributions: A.J.D., E.A.M., and D.W.M. performed research and wrote the paper.

The authors declare no conflict of interest.

This article is a PNAS Direct Submission. A.J.T. is a guest editor invited by the Editorial Board.

[1]To whom correspondence should be addressed. E-mail: amy.dickman@zoo.ox.ac.uk.

Tanzania, a critically important area for carnivores, average per capita income is approximately $500 annually (15). Alleviating such poverty is clearly a moral imperative, and conservationists are increasingly considering how mechanisms to facilitate human–carnivore coexistence can benefit people and predators. However, accurately defining poverty (and therefore measuring poverty alleviation, or escape from poverty traps) is complex. Communities which score poorly on traditional poverty indicators, such as access to education and markets, or cash income and expenditure, may nevertheless be rich in assets such as livestock, which represent significant economic and social worth (10). Moreover, distinctions should be made between transitory poverty, which affects various people temporarily, and chronic poverty, whereby the same people remain trapped in long-term poverty (16). In many cases, the people still coexisting with large carnivores are traditional pastoralists, who are particularly susceptible to long-term poverty traps (17). They have a strong cultural reliance upon their stock, and often lack other assets, making them unlikely to have alternative means of surviving environmental shocks and ensnaring them in a "cultural poverty trap." Furthermore, pastoralists are often politically marginalized and suffer markedly from the failure of social institutions, both in terms of market failures, whereby the value of their land for wildlife is not realized at a local level, and political failures, whereby issues such as widespread corruption mean that externally generated revenue is often not passed down to poor households. Livestock assets are the primary form of wealth acquisition and storage in these traditional communities, and stock losses, such as from depredation, can have harsh social consequences in addition to significant economic costs.

Overall, human–carnivore coexistence imposes substantial, diverse costs on local people, and although carnivore populations can generate considerable revenue, many existing revenue streams in developing countries are diverted externally rather than being captured locally, posing significant obstacles to incentivizing effective "on-the-ground" conservation (18). This poor cost–benefit ratio at a local level leads to people extirpating such species from human-dominated land, and this has been one of the most significant drivers of the widespread declines in carnivore populations described earlier. Improving this situation is an urgent priority, as much of the remaining range of threatened large carnivores is on human-dominated land: for instance, more than 80% of remaining habitat occupied by tigers is outside reserves (19), and this figure increases to more than 90% for jaguars and snow leopards (*Panthera uncia*) (20). The ideal outcome is to develop strategies that not only translate the high global value of large carnivores into sufficient, relevant incentives for their conservation at a local scale, but also enable local people to escape from existing poverty traps. Our objectives are to review the main financial mechanisms currently used to promote human–carnivore coexistence, discuss their pitfalls and potentials in terms of carnivore conservation and poverty alleviation, and suggest how these mechanisms could potentially be combined and improved in the future, with benefits for both people and predators.

Using Financial Mechanisms to Realign Global and Local Values

The central problem in carnivore conservation is a classic "market failure," whereby a globally valued resource is depleted because of a lack of sufficient economic incentives to maintain it locally (18). Various schemes have been developed to try to remedy this problem—we collectively term these approaches "payments to encourage coexistence" (PEC), which we define as schemes whereby (*i*) carnivore presence is ascribed high external value, (*ii*) which is translated into local payments for those negatively affected by carnivore presence (*iii*) to encourage human–carnivore coexistence. Some PEC schemes take an ex-post approach, covering individual costs as they are imposed by carnivores, whereas others provide payments based on the assumption that carnivores will impose some general level of cost. Some of these approaches, such as direct payments, can also be considered forms of payments for ecosystem services (PES), but most do not fulfill the strict criteria of PES (described later) and therefore warrant the broader grouping of PEC. Ecological modeling approaches have highlighted the theoretical potential of financial mechanisms such as PEC to incentivize carnivore conservation, as they provide valuable economic revenue for local people, and could help alleviate poverty by providing payments linked to conservation (21, 22).

Determining the correct level of payments involved in PEC is critically important: payments must be sufficient to outweigh the costs imposed on local people, but also in proportion to the benefits produced for the international community. In addition, there will be external costs associated with providing incentives for local compliance with the scheme. Following Pagiola and Platais (23), we have developed a schematic model of maximum and minimum payments as they relate to

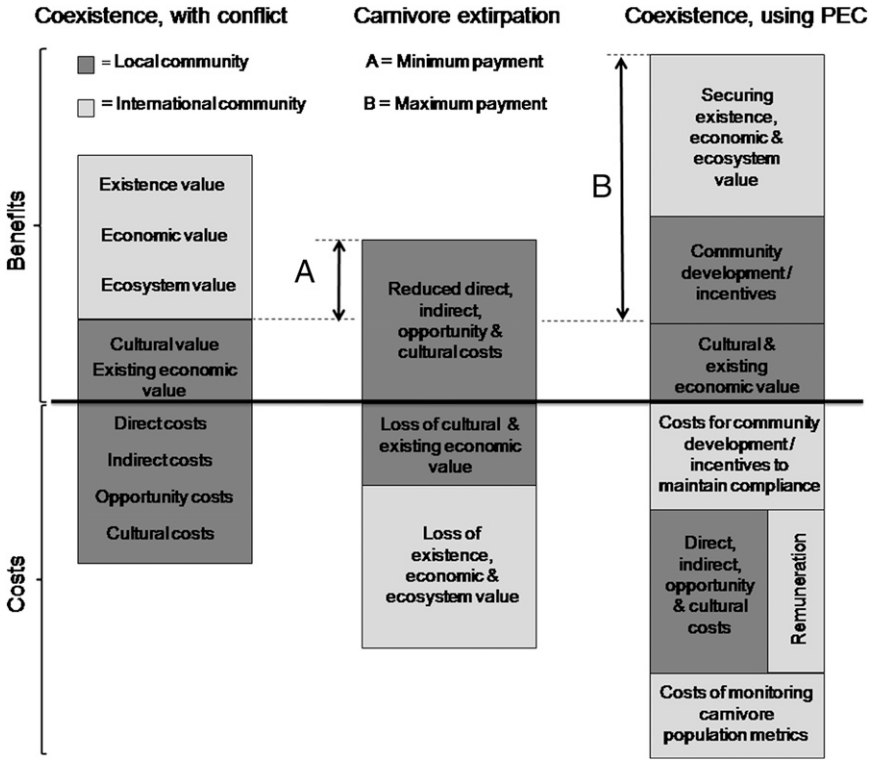

Fig. 1. The costs and benefits of carnivore coexistence and extirpation as they relate to local and international communities. This reveals the minimum (*A*) and maximum (*B*) payments needed under PEC to encourage local communities to coexist with carnivores rather than extirpate them. This illustration was developed following the schematic concept used by Pagiola and Platais (23).

carnivore conservation (Fig. 1). Under a coexistence-with-conflict scenario, the international community retains the existence, economic, and ecosystem value provided by carnivores on private land, whereas local communities suffer the direct, indirect, opportunity, and cultural costs. However, local communities often recognize some cultural value from carnivore presence, and carnivores may also have some local economic value, for instance through any revenue that already reaches local people from carnivore-related tourism. However, the majority of current revenue streams from tourism are largely captured externally (24), and any local economic value is usually outweighed by the costs of coexistence. Under a scenario in which carnivores are extirpated, local communities benefit from reductions in all the costs described, but also lose the cultural and existing economic value of carnivores: a net benefit (A). The international community, however, gains nothing under this scenario, and loses all the value attributed to carnivores in those areas. Financial mechanisms can help encourage coexistence if they make payments that are at least equal to the carnivore-free local benefit (A), and may be as large as the value of recompensing these costs and providing incentives to maintain compliance, plus the overall value attributed to the resource by the international community (B). In addition to these payments for costs and compliance, the international community will also bear the costs of monitoring target carnivore population metrics, to evaluate the success of the PEC scheme.

Here, we discuss the operational issues inherent to the use of PEC, and then specifically examine the main approaches used in the field of carnivore conservation, namely (*i*) compensation and insurance schemes, (*ii*) revenue-sharing initiatives, and (*iii*) conservation payments. We assess their practical success at facilitating carnivore conservation, and examine their likely impacts in terms of reducing poverty within local communities.

Operational Issues Associated with PEC. To ensure that PEC provides benefits to people and predators, a number of factors should be considered. First, is there a threat to the carnivore population in question, which is likely to be mitigated as a result of PEC? If this is not the case—for instance, a carnivore population under consideration for PEC is likely to be conserved for other reasons anyway—the scheme provider will not gain anything in return for their payments, often referred to as lack of additionality (25). Second, can PEC be enacted at a scale likely to secure conservation of the target population of carnivores? These species roam over vast areas, often covering a range of different land tenure arrangements and resource ownership rights, which complicates payment allocation and distribution. In some cases, there is good congruency between the scale of the target species' range and the scale of the land tenure system and number of payment recipients (26), but this must be considered for each individual PEC scheme. If there is poor congruency between the spatial scales of the species range and that of payment recipients, Zabel and Engel (26) suggest that payments may have to be made according to intermediate conservation goals that can be observed locally at a scale relevant to the recipients. An additional consideration is that the ranges of conflict-causing species often incorporate areas used by the landless poor, who are often those worst affected by conflict and least empowered to receive benefits from PEC. If a scheme involves only a small number of people and/or a small area, and ignores the views and actions of those without formal tenure rights, it is unlikely to secure effectively the conservation of wide-ranging, conflict-causing animals, and may also exacerbate social inequities (27). Moreover, lack of clarity over the ownership of land and/or wildlife, or significant variation in this across a target species' range, will substantially hinder the effective provision of PEC payments.

Even if it is clear to whom payments should go, corruption or weak institutional mechanisms may result in payments being unfairly captured by local elites, therefore not achieving the desired conservation and poverty alleviation benefits. Furthermore, in areas of high human density, it is hard to provide economic incentives to all individuals, sufficient to offset the costs incurred at a personal or household level. Under such circumstances, it is important not to view PEC as a standalone solution, but also to focus upon reducing the costs of carnivore presence as much as possible, so even relatively small payments are sufficient to outweigh the costs imposed. Another issue is that of "leakage"—for example, if you pay people in one area to conserve carnivores, does the level of conflict and persecution increase in nearby areas, resulting in no overall increase in conservation benefits? Perverse incentives or "moral hazard" may also result from poorly designed PEC schemes; for example, people may be incentivized to reduce defense of livestock to obtain economic compensation for depredation (28). Each PEC approach has its own specific set of operational issues, constraints, and advantages, and these are examined in more detail in the subsequent sections.

Compensation and insurance schemes. Given the high economic costs often imposed by carnivores at a local scale, one approach is for the international community to offset costs as they are incurred through direct compensation of individuals affected, thereby hopefully reducing animosity toward, and retaliatory killing of, the species in question. Numerous such compensation schemes have been implemented to address conflicts between humans and large carnivores. The costs associated with livestock depredation are frequently cited as a key reason for people's animosity toward carnivores (29), so directly compensating for these costs seems an effective strategy for minimizing conflict and encouraging more peaceful human–carnivore coexistence. The concept is simple: any suspected livestock depredation incident is independently investigated, and if the loss is attributed to a predator covered by the scheme, a payout is made directly to the affected owner. This approach of directly paying those affected by carnivores is likely to be particularly effective at reducing individual anger, which is important because carnivore persecution by even a few hostile individuals can have significant impacts in terms of decreasing the viability of a target carnivore population (30). The conservation aspect of such schemes is sometimes emphasized by forbidding anyone involved to kill any of the carnivores concerned, with fines and/or temporary cessation of compensation payments imposed for any transgressions (31). Insurance schemes are similar to compensation, but are often more community-driven and require participants to pay a premium for their involvement, ideally reducing the need for substantial external funding. Compensation and insurance initiatives have certainly achieved some success: a privately funded "Defenders of Wildlife" compensation scheme for wolf damage operational from 1987 to the present was credited as reducing ranchers' animosity toward wolf recovery in Yellowstone National Park and paving the way for further wolf reintroductions (28). A compensation scheme on Mbirikani Group Ranch in Kenya was also linked to fewer lions being killed (31).

However, the imposition of financial penalties to avoid moral hazard (e.g., paying only a proportion of market value if the depredation incident was linked to poor husbandry) means that affected stock owners are rarely fully compensated for the economic cost of depredation even when it has been verified, so carnivores still impose a substantial net cost. In Botswana, state-funded compensation for lost livestock was set at 80% of market value, but penalties for grazing in protected areas, and lack of verification, meant that cattle ranchers recouped only 42% of the value of stock lost, with an average annual loss to

lions, after compensation, of $168 (32). This is particularly galling, as livestock predation may cost more than the market value of the livestock because of the transaction costs of claiming for compensation or the lost potential value of a pregnant or young animal (28). Conversely, livestock producers may take advantage of compensation or insurance scheme and fraudulently claim that stock lost as a result of other factors were depredated, increasing the economic burden of such a scheme (28). Despite the intense hostility engendered by depredation, local interest and buy-in to insurance programs can be surprisingly low, especially where it is a novel approach and/or the rate of depredation is low (33). Furthermore, payments for verified depredation do not cover all of the ancillary costs of living alongside carnivores, such as the direct and opportunity costs incurred by guarding livestock from the risk of predation (6, 12). Therefore, even if insurance or compensation schemes reduce the likelihood of retaliatory carnivore killing, incentives still remain for preemptive killing.

Ultimately, although compensation and insurance schemes can undoubtedly reduce the financial impacts of predators, carnivores often still impose more costs than benefits on local people. Costs are likely to be even higher in poor pastoral areas, where illiteracy hampers the submission of claims for compensation, and where poor institutional mechanisms heighten the chances of fraud and corruption. Moreover, these initiatives can intensify poverty traps by encouraging migration of people into areas where compensation schemes exist, thereby increasing competition over resources such as pastoral grazing land, and reducing herd sizes and productivity (34). There are also limits to the usefulness of economic compensation: for instance, it will never adequately make restitution for the loss of human life, although compensation schemes do exist for such incidents. In Himachal, India, compensation of approximately $2,170 is paid for each human killed or permanently incapacitated by a wild animal, whereas the rate for grievous human injury is approximately $700.

In terms of conservation impacts, there is mixed evidence for compensation and insurance schemes significantly reducing human–carnivore conflict: in India, a communal insurance and incentive scheme has been successful in safeguarding snow leopards and their prey, and reducing levels of depredation and snow leopard persecution (35). However, this is not always the case, especially for compensation rather than insurance schemes: a study in Wisconsin found that people who were compensated for losses to wolves were no more tolerant of them than those who were not compensated (36). Furthermore, compensation schemes can sometimes be detrimental to conservation. Even with penalties, compensation can create a perverse incentive by decreasing people's motivation to protect stock from predators, ultimately increasing losses and exacerbating conflict. Lowered costs of depredation may also result in people raising their stocking rates and intensifying grazing around conservation areas, leading to a decline of wild prey, an increase in human–carnivore conflict, and intensification of pastoral poverty traps (34). Finally, compensation and insurance schemes usually require significant external funding, the permanence of which is often an issue, and consequently many compensation schemes have ended in bankruptcy (34). Implementing such schemes raises expectations among stakeholders, and if they fail, it can intensify negative attitudes toward focal predators (37). Overall, compensation and insurance schemes may potentially seem to be useful tools for reducing the direct economic impact of predators on people, but they fail to provide any real incentive for local people to actually deliver conservation. Evidence from the field suggests they are unlikely to produce substantial benefits in terms of long-term conservation or poverty alleviation, and may even have negative consequences.

Revenue-sharing initiatives. The major failing of compensation and insurance schemes is that the costs of carnivore presence still usually outweigh the benefits, providing no incentive for conservation. One alternative is to channel some of the revenue generated by wildlife—whether through tourism, trophy hunting, or other activities—back to local communities, and provide benefits to help offset costs not covered by compensation. The value of community remuneration for conservation appeared evident in Kenya: in areas where most of the revenue from ecotourism was retained by the tourism industry and the government, 29% to 65% of wildlife was lost between 1977 and 1994; in areas where revenues were shared among group ranches, wildlife held its own; and on private land where owners received all of the revenue, wildlife increased by 12% (38). However, recent assessments of wildlife trends in Kenya are less positive, revealing marked declines in wildlife numbers regardless of land-use type (39). In Namibia, the establishment of communal conservancies, whereby local stakeholders retain all revenue from wildlife use, has been associated with significant increases in lion populations (40). A tourism revenue-sharing programmed around three parks in Uganda resulted in more than $80,000 being invested in schools, clinics, and infrastructure, and nearly three quarters of local people believed this scheme had improved their attitudes toward the parks (41).

However, distributional inequalities mean that the majority of economic benefits from such schemes often accrue to small groups of people, such as park or urban "gateway" residents, rather than villagers in more remote locations, who suffer intense costs of wildlife presence (42). There is also a risk of "elite capture" even at the village scale, with marginalized groups such as pastoralists benefiting least from in-town initiatives such as schools and clinics, while still suffering most of the costs. Critically, payments do not necessarily go to those most impacted by carnivore presence, so revenue sharing is unlikely to reduce animosity and hostility among those suffering most acutely from depredation; those people may still kill carnivores. Linked with this is the fundamentally important issue that most revenue-sharing initiatives are not conditional upon recipients delivering measurable conservation benefits, such as securing target carnivore populations, leading to situations in which people may feel positive toward the revenue-generating activity but remain negative toward wildlife. For example, in Nepal, people who received benefits from the Makalu–Barun National Park and Conservation Area strongly supported future tourism development in the area, but viewed protecting wildlife as a low priority and pressed for more lethal control of wild animals (43). Such schemes can also have unexpected consequences: by improving the cost–benefit ratio of living in reserve-adjacent areas, a favorability threshold may be crossed, leading to in-migration of more people. This can increase competition for grazing land and other resources and result in increased settlement and land conversion in wildlife-rich areas (44), all of which can reinforce poverty traps, particularly for pastoralists, and ultimately lead to negative impacts on wildlife.

Another complication is that many biodiversity-rich areas are remote, poor, and lack good infrastructure for tourism, limiting the potential economic returns (45). Even in cases in which local people obtain wildlife-related revenue, having wildlife present and gaining from it (generally via tourist revenues) may still not be the most profitable use of land. Protecting land for wildlife can result in local communities incurring significant opportunity costs in terms of restricted grazing, and reduced resource use or hunting, as well as forgoing alternative land use options (46, 47). Setting aside land for conservation can limit people's economic opportunities and restrict their land use options, and such "forced primitivism" can cause anger and resentment toward conservation

agencies and wildlife (48, 49). Norton-Griffiths (50) estimated a discrepancy of $26.8 million between the annual returns from conservation to Maasai landowners in Kenya and the potential net returns if their land were fully developed, and suggested that conservation is condemning these landowners to a poverty trap. Similarly, households adjacent to Madagascar's Mantadia National Park were calculated to suffer losses of $419 (more than half the annual per capita income), primarily because of restricted access to agricultural land (51). It is clear that, under these scenarios, conservation still produces a net negative effect on affected communities, and although the provision of wildlife-related revenue may sometimes be useful in softening the jaws of local poverty traps, there is little evidence for them helping people ultimately escape from chronic poverty.

Conservation payments. To strengthen the linkage between economic incentives and conservation, payments for conservation are becoming increasingly common (18). The defining characteristic of this approach, in contrast to other forms of PEC, is that payments are linked specifically to the production of the desired environmental output (e.g., maintenance of carnivores on private land) rather than to indirect inputs assumed to affect the production of that service, such as the reduction of conflict (52). Such payments have been used to encourage carnivore conservation in Mexico, where ranchers are paid between $50 and $300 if camera-traps record a jaguar, puma (*Puma concolor*), ocelot (*Leopardus pardalis*), or bobcat (*Lynx rufus*) on their land (18, 53). In areas where large carnivores are particularly rare, proxy species can be used to determine payments—for instance, in Nepal, accurately monitoring snow leopards is difficult, so local people are rewarded for improving the habitat and population of an important prey species, the bharal (*Pseudois nayaur*), and such rewards are contingent upon villagers not killing snow leopards (18, 35). Many of these conservation payment approaches can be categorized as PES, defined by Wunder (25) as (*i*) a voluntary transaction (*ii*) in which a well defined environmental service or land use likely to secure that service (*iii*) is bought by at least one buyer (*iv*) from at least one provider, (*v*) if and only if the service provider secures service provision (i.e., conditionality).

In 1996, the Swedish government opted for a performance payment scheme to obtain and maintain stable populations of wolves, lynx (*Lynx lynx*), and wolverines (*Gulo gulo*), most of which live in Sami pastoralist rangelands (54). The 20,000 Sami pastoralists in Sweden, who live in 51 villages, are traditional reindeer (*Rangifer tarandus*) herders, and 2,500 of them still rely on the reindeer business for full-time employment (54). The Sami often suffer substantial reindeer depredation and can engage in retaliatory poaching, which is a major cause of mortality for adult lynx and wolverines in Sweden (54). Under the scheme, payments are made to each of the 51 villages contingent on the number of carnivore reproductions certified on village reindeer grazing land, with the amount calculated to offset all future costs imposed by the young carnivores during their lifetimes (54). In 2007, the payment for each certified lynx and wolverine reproduction was approximately $29,000, and the villages manage, allocate, and disburse the payments as they see fit (54). The scheme appears to have been successful, as the number of certified wolverine reproductions in the reindeer area has now exceeded the 90-per-year target, although it is not yet possible to confirm empirically that this is a result of the payment scheme (26).

Conservation payments have several benefits for people and predators: they are likely to provide additionality, as they create a direct incentive for maintaining carnivores, whereas service providers are less constrained, and able to act in the manner optimal to their specific conditions to reach the desired endpoint, often resulting in greater cost effectiveness (54, 55). Payments are usually independent of levels of depredation, thereby avoiding moral hazard, and entail low transaction costs for livestock-keepers, as they do not have to search for depredated livestock or submit claims for compensation. Furthermore, unlike schemes linked to protected areas, which can impose substantial opportunity costs, these payments actually reduce the costs of maintaining traditional lifestyles in areas where humans and carnivores coexist, helping people maintain their cultural integrity and avoid traditional pastoral poverty traps.

However, there are issues related to risk and distortion that should be considered. The service provider may incur production risks if they invest in certain costly strategies that do not ultimately lead to an increase in service production (52), or the benefits of such investments are outweighed by exogenous shocks such as severe drought or disease independently reducing the numbers of carnivores. Particularly in poor pastoral areas, reliance on such schemes can exacerbate sensitivity to environmental fluctuations, as such shocks will often not only affect household livestock assets but also wildlife populations, leading to a reduction in external payments at the time they are most needed. Payments to individual farmers—which specifically reduce antagonism among the people most affected by carnivore presence—require well defined land tenure and property rights, whereas collective payments, such as to a village, require functional systems of collective action. In some cases, elite capture of benefits can occur, with poorer, marginalized people (often pastoralists) and the landless poor too powerless to acquire a fair share of the revenue provided. In situations with insecure land tenure, as in many pastoral areas, conservation payments can make land more economically attractive and vulnerable to external takeover by more powerful elites, thereby exacerbating the poverty of the original users (27). These schemes can also entail high transaction costs for the buyer, for instance by intensively monitoring carnivore populations (54), and uncertainties exist about how to establish accurately the baseline conservation status of a carnivore population, as well as how to determine and measure accurately the desired conservation outcome. There is a possibility of distortion if changes in the metric being measured does not accurately reflect changes in the real target, such as the size of the focal carnivore population (52). This is of particular concern in schemes in which proxy measures are used: for instance, in the snow leopard example given earlier, it is conceivable that participants could encourage bharal population growth but still secretly kill snow leopards, so success as measured by the proxy indicator would not accurately reflect a positive change in terms of snow leopard conservation.

Despite these caveats, however, there is increasing evidence from the field that conservation payments can be a valuable tool for encouraging human–predator coexistence, and for providing important revenue to local communities (54). Models have shown that PES schemes in particular can successfully attain conservation and poverty alleviation objectives (56), and there is clear evidence of them having a positive impact on poor service providers through increased income and greater land security (57), but as yet there is little empirical evidence of them significantly reducing poverty in the field of carnivore conservation. Nonetheless, they are undoubtedly an important tool for facilitating the ongoing coexistence of people and carnivores, and for translating global existence value into tangible economic value at a local level.

Improving PEC: Developing a Combined Method from the Lessons Learned. Strategies for human–carnivore coexistence have gradually evolved from a baseline of ignoring local peoples' needs, toward offsetting the direct costs of carnivore presence and then toward developing methods that are actually intended to provide net

benefits associated with that presence. All the schemes outlined have individual strengths, and we suggest that a combination of approaches could be the most beneficial for successfully achieving human–carnivore coexistence. An "ideal" PEC would: (*i*) minimize conflict by specifically targeting payments to those most directly affected by carnivores, (*ii*) reduce the direct costs of human–carnivore coexistence, (*iii*) provide local people with additional revenue directly linked to carnivores, (*iv*) avoid moral hazard and perverse incentives, (*v*) not require significant additional external revenue, (*vi*) specifically link payments to desired conservation outcomes, and (*vii*) be likely to have a positive impact on human poverty. None of the existing schemes, as they stand alone, fulfill all these criteria: compensation/insurance achieves only *i* and *ii*, whereas revenue sharing achieves only *iii*, *v*, and *vii*, although it does have some link to conservation success, as revenues will eventually decrease if wildlife populations decline. Compensation payments achieve *iii*, *iv*, *vi*, and *vii*, but fail to target individuals most affected by wildlife damage, do not actively reduce that damage, and are heavily dependent on external funding.

For greatest success, a PEC scheme may have to combine several of the existing approaches. A PEC fund could be established from all available revenue streams (Fig. 2), and the money primarily disbursed as conservation payments, as this approach is the only one that directly incentivizes human–carnivore coexistence. To avoid issues such as elite capture and payments failing to reach the entire community, including those without formal land tenure rights, a subset of the fund could be allocated to community-driven development initiatives, such as the building of cattle dips, which would help reduce levels of stock loss to disease and help pastoralists secure their livelihoods. In areas where pastoral households have relatively few stock, the fund could help develop alternative initiatives, such as investment in child nutrition, health care, and education, which would have widespread benefits across the community. However, none of these approaches specifically target those most affected by depredation, so a portion of the fund could be paid out as compensation to those who directly suffer from losses to carnivores, although such payments should be linked to husbandry standards to avoid moral hazard. This kind of combined approach would achieve all of the criteria of an ideal PEC scheme, apart from *v*, as it would need significant external funding. However, as the idea of international "conservation credits" expands, and the international community increasingly realizes the need to internalize the economic value of wild carnivore populations, funds for such initiatives are likely to increase.

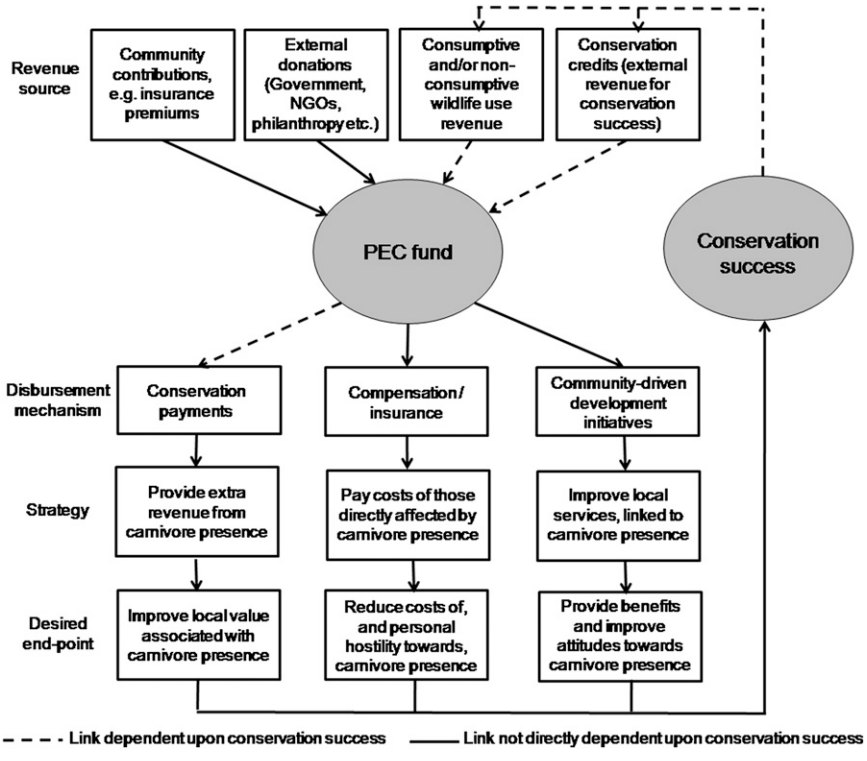

Fig. 2. Example of how existing PEC strategies could be incorporated under a single scheme to encourage carnivore conservation on human-dominated land.

The scale of implementation of existing financial mechanisms varies widely, from state-led initiatives, such as the Swedish performance payments and the livestock compensation schemes in Botswana, to nonstate initiatives such as the Defenders for Wildlife program in Yellowstone, a privately funded member organization. To our knowledge, no combined PEC schemes currently exist, and developing such a mechanism involves various logistical challenges, such as defining who owns the resource; how funds are to be generated, maintained, and distributed; and verifying payments. However, none of these challenges are exclusive to a combined PEC scheme, so there is scope to learn from and adapt methodologies already developed by existing projects. The specifics of any project will be highly dependent on local circumstances, and a detailed understanding of the local system is critically important for scheme development: for instance, the strength and efficacy of local collective action determines whether payments should be made at an individual level, or to a village or other unit. However, there are some generalizable key priorities, including the setting of clearly defined goals and objectives, establishment of accurate and repeatable methods for monitoring the metric for which payments are made, generation and long-term commitment of funds, a locally appropriate mechanism for distributing payments at the relevant scale, and genuine engagement of local stakeholders. Determining which initiatives would most benefit the community concerned is also highly site-specific, and would have to be developed in close collaboration with local people. For the compensation element of the scheme, managers would have to decide how to verify losses, the size of payments, which livestock husbandry methods were linked to payments, and how such a scheme fits into national policies. This combined PEC approach is by no means a panacea for all the problems of human–carnivore coexistence, and should be combined with efforts to reduce the costs of carnivore presence, but by incorporating the most promising aspects of existing PEC schemes, we can move forward and develop new approaches to effectively tackle this complex issue.

Conclusion

PEC schemes are not a silver-bullet solution to the problem of conserving large carnivores on human-dominated land. In some areas, the high costs imposed by carnivore presence—such as where man-eating is common—means that PEC incentives may fail to facilitate coexistence. In such places, alternative strategies such as fencing reserves to separate humans and wildlife, or encouraging people to

relocate from key wildlife areas, may be necessary. However, given the burgeoning human population and demand for land, some level of human-carnivore coexistence will increasingly be inevitable, and in these circumstances, PEC approaches can be valuable in converting the benefits of carnivores from an abstract externality to a tangible reality for local people. PEC recognizes that, if external beneficiaries want the long-term conservation of globally iconic but locally problematic species, they will have to develop and fund strategies to outweigh the local costs incurred, which will require significant investment from stakeholders such as governments and conservation agencies. Promising headway has been made in this regard, especially with regard to conservation payments, but predators pose a particularly tricky case, as their persecution results not simply from economic loss but also from deep-rooted cultural values. Schemes must be developed that not only provide compensatory economic revenue, but address these noneconomic factors and cultural norms as well. One innovative model has been developed in Kenya, where the cultural aspects of Maasai lion killing are incorporated into a "Lion Guardians" program where warriors "hunt" lions to radio-collar and monitor them, thereby receiving economic incentives through valuable training and employment while still maintaining their traditions and receiving cultural recognition (58). The program appears successful: to date, no lions have been speared on Mbirikani Ranch, where the Lion Guardians are working, compared with more than 30 spearings on neighboring ranches. As the program only began in 2006, it is hard to evaluate properly its success and demonstrate any significant increases in lion populations linked to the program, but in 2010 alone, Lion Guardians actively prevented 27 hunting parties from killing lions. So far, this scheme has been used only in a trial population of fewer than 250 lions, but extensions to larger lion populations are currently under way. Such initiatives still require significant external funding to sustain them, and although promising headway has been made with ideas such as biodiversity swaps and conservation credits (59, 60), effective long-term provision of PEC will rely heavily upon a significant increase in the developed world's willingness and ability to pay for such schemes.

Ultimately, any scheme needs to be tailored carefully to the individual situation to avoid problems of perverse incentives, additionality, and leakage; to ensure that the desired conservation outcomes are achieved; and to satisfy the economic and cultural needs of people bearing the costs associated with living with wildlife. Moreover, there is a pressing need to develop PEC approaches that can be scaled up to a landscape level, involving all of the disparate groups of stakeholders—from the landless poor to wealthy farmers—affected by carnivore presence across the target area. The "holy grail" for truly integrating carnivore conservation with the communities who live with them is a situation in which local people receive tangible, commensurate, and equitably distributed benefits from predators that outweigh all the diverse costs, and carnivore-related revenue can help people escape existing poverty traps. This remains an elusive scenario, but valuable lessons have been learned from implementing PEC approaches, and combining the best aspects of these different methods could help translate the external values associated with carnivores down to the local level, with important potential benefits for people and predators.

ACKNOWLEDGMENTS. The authors thank Ros Shaw and Sandra Baker for helping to collate the material needed for this manuscript, and their input toward and editing of an earlier version. A.J.D. is a Kaplan Senior Research Fellow. E.A.M. was supported by a Kaplan Scholarship from Panthera.

1. International Union for Conservation of Nature (2007) *Regional Conservation Strategy for the Cheetah and African Wild Dog in Eastern Africa* (IUCN SSC Cat and Canid Specialist Groups, Gland, Switzerland).
2. International Union for Conservation of Nature (2006) *Regional Conservation Strategy for the Lion Panthera leo in Eastern and Southern Africa* (IUCN SSC Cat Specialist Group, Gland, Switzerland).
3. Macdonald DW, Loveridge AJ, Nowell K (2010) Dramatis personae: an introduction to the wild felids. in *Biology and Conservation of Wild Felids*, eds Macdonald DW, Loveridge AJ (Oxford Univ Press, Oxford), pp 3–58.
4. Macdonald DW, Sillero-Zubiri C (2004) Dramatis personae. in *Biology and Conservation of Wild Canids*, eds Macdonald DW, Sillero-Zubiri C (Oxford Univ Press, Oxford), pp 3–36.
5. Macdonald DW (2001) Postscript - carnivore conservation: science, compromise and tough choices. in *Carnivore Conservation*, eds Gittleman J, Funk S, Macdonald D, Wayne R (Cambridge Univ Press, Cambridge, UK), pp 524–538.
6. Macdonald DW, Loveridge AJ, Rabinowitz A (2010) Felid futures: crossing disciplines, borders and generations. in *Biology and Conservation of Wild Felids*, eds Macdonald DW, Loveridge AJ (Oxford Univ Press, Oxford), pp 599–649.
7. Holmern T, Nyahongo J, Roskaft E (2007) Livestock loss caused by predators outside the Serengeti National Park, Tanzania. *Biol Conserv* 135:518–526.
8. Wang SW, Macdonald DW (2006) Livestock predation by carnivores in Jigme Singye Wangchuck National Park, Bhutan. *Biol Conserv* 129:558–565.
9. Rasmussen GSA (1999) Livestock predation by the painted hunting dog Lycaon pictus in a cattle ranching region of Zimbabwe: A case study. *Biol Conserv* 88:133–139.
10. Little PD, McPeak J, Barrett CB, Kristjanson P (2008) Challenging orthodoxies: Understanding poverty in pastoral areas of East Africa. *Dev Change* 39:587–611.
11. Lybbert TJ, Barrett CB, Desta S, Coppock DL (2004) Stochastic wealth dynamics and risk management among a poor population. *Econ J* 114:750–777.
12. Thirgood S, Woodroffe R, Rabinowitz A (2005) The impact of human-wildlife conflict on human lives and livelihoods. in *People and Wildlife: Conflict or Coexistence?* eds Woodroffe R, Thirgood S, Rabinowitz A (Cambridge Univ Press, Cambridge, UK), pp 13–26.
13. Löe J, Röskaft E (2004) Large carnivores and human safety: A review. *Ambio* 33:283–288.
14. Galaty JG (1982) Being "Maasai"; being "people of cattle": Ethnic shifters in East Africa. *Am Ethnol* 9:1–20.
15. Jin S, Deininger K (2009) Key constraints for rural nonfarm activity in Tanzania: Combining investment climate and household surveys. *J Afr Econ* 18:319–361.
16. Carter MR, Barrett CB (2006) The economics of poverty traps and persistent poverty: an asset-based approach. *J Dev Stud* 42:178–199.
17. McPeak JG, Barrett CB (2001) Differential risk exposure and stochastic poverty traps among East African pastoralists. *Am J Agric Econ* 83:674–679.
18. Nelson F (2009) Developing payments for ecosystem service approaches to carnivore conservation. *Hum Dimens Wildl* 14:381–392.
19. Miquelle DG, et al. (1999) Hierarchical spatial analysis of Amur tiger relationships to habitat and prey. in *Riding the Tiger: Tiger Conservation in Human-Dominated Landscapes*, eds Seidensticker J, Christie S, Jackson P (Cambridge Univ Press, Cambridge), pp 71–99.
20. Nowell K, Jackson P (1996) *Wild Cats: Status Survey and Conservation Action Plan* (Burlington, Cambridge).
21. Zabel A, Pittel K, Bostedt G, Engel S (2009) *Comparing Conventional and New Policy Approaches for Carnivore Conservation – Theoretical Results and Application to Tiger Conservation* (International Institute for Environment and Development, London).
22. Landell-Mills N, Porras I (2002) *Silver Bullet or Fool's Gold? A Global Review of Markets for Forest Environmental Services and Their Impact on the Poor* (International Institute for Environment and Development, London).
23. Pagiola S, Platais G (2007) *Payments for Environmental Services; From Theory to Practice* (World Bank, Washington, DC).
24. Banerjee A (2010) Tourism in protected areas: Worsening prospects for tigers? *Econ Polit Wkly* 45:27–29.
25. Wunder S (2005) *Payments for Environmental Services: Some Nuts and Bolts* (CIFOR, Bogor Barat, Indonesia).
26. Zabel A, Engel S (2010) *Performance Payments: A New Strategy to Conserve Large Carnivores in the Tropics?* (Institute for Environmental Decisions, Zurich).
27. Pagiola S, Arcenas A, Platais G (2005) Can payments for environmental services help reduce poverty? An exploration of the issues and the evidence to date from Latin America. *World Dev* 33:237–253.
28. Nyhus P, Fischer F, Madden F, Osofsky S (2003) Taking the bite out of wildlife damage: The challenge of wildlife compensation schemes. *Conserv Prac* 4:37–40.
29. Sillero-Zubiri C, Laurenson MK (2001) Interactions between carnivores and local communities: conflict or coexistence? in *Carnivore Conservation*, eds Gittleman JL, Funk SM, Macdonald DW, Wayne RK (Cambridge Univ Press, Cambridge, UK), pp 282–312.
30. Woodroffe R, Frank LG (2005) Lethal control of African lions (Panthera leo): Local and regional population impacts. *Anim Conserv* 8:91–98.
31. Maclennan SD, Groom RJ, Macdonald DW, Frank LG (2009) Evaluating a compensation scheme to bring about pastoralist tolerance of lions. *Biol Conserv* 142: 2419–2427.
32. Hemson G, Maclennan S, Mills G, Johnson P, Macdonald D (2009) Community, lions, livestock and money: A spatial and social analysis of attitudes to wildlife and the conservation value of tourism in a human-carnivore conflict in Botswana. *Biol Conserv* 142: 2718–2725.
33. Miquelle D, et al. (2005) Searching for the coexistence recipe: a case study of conflict between people and tigers in the Russian Far East. in *People and Wildlife: Conflict or Coexistence?* eds Woodroffe R, Thirgood S, Rabinowitz A (Cambridge Univ Press, Cambridge, UK), pp 305–322.
34. Bulte EH, Rondeau D (2005) Why compensating wildlife damages may be bad for conservation. *J Wildl Manage* 69:14–19.

35. Mishra C, et al. (2003) The role of incentive programs in conserving the snow leopard. *Conserv Biol* 17: 1512–1520.
36. Naughton-Treves L, Grossberg R, Treves A (2003) Paying for tolerance: rural citizens' attitudes toward wolf depredation and compensation. *Conserv Biol* 17:1500–1511.
37. Montag J (2003) Compensation and predator conservation: Limitations of compensation. *Carnivore Damage Prevention News* 6:2–5.
38. Norton-Griffiths M (1998) The economics of wildlife conservation policy in Kenya. in *Conservation of Biological Resources*, eds Milner-Gulland EJ, Mace R (Blackwell, Oxford), pp 279–293.
39. Western D, Russell S, Cuthill I (2009) The status of wildlife in protected areas compared to non-protected areas of Kenya. *PLoS ONE* 4:e6140.
40. Namibian Association of Community Based Natural Resource Management (2008) *Namibia's Communal Conservancies: A Review of Progress in 2007* (NACSO, Windhoek, Namibia).
41. Archabald K, Naughton-Treves L (2001) Tourism revenue-sharing around National Parks in western Uganda: Early efforts to identify and reward local communities. *Environ Conserv* 28:135–149.
42. Walpole MJ, Goodwin HJ (2000) Local economic impacts of dragon tourism in Indonesia. *Ann Tourism Res* 27:559–576.
43. Mehta JN, Kellert SR (1998) Local attitudes towards community-based conservation policy and programmes in Nepal: A case study in the Makalu-Barun Conservation Area. *Environ Conserv* 25:320–333.
44. Wittemyer G, Elsen P, Bean WT, Burton AC, Brashares JS (2008) Accelerated human population growth at protected area edges. *Science* 321:123–126.
45. Walpole MJ, Thouless CR (2005) Increasing the value of tourism through non-consumptive use? Deconstructing the myths of ecotourism and community-based tourism in the tropics. in *People and Wildlife: Conflict or Coexistence?* eds Woodroffe R, Thirgood S, Rabinowitz A (Cambridge Univ Press, Cambridge, UK) pp 122–139.
46. Gibson CC, Marks SA (1995) Transforming rural hunters into conservationists: An assessment of community-based wildlife management programs in Africa. *World Dev* 23:941–957.
47. Redford KH, Wilkie DS, Fearn E (2007) Introduction. in *Protected Areas and Human Livelihoods*, eds Redford KH, Fearn E (Wildlife Conservation Society, New York), pp 2–6.
48. Goodland R (1982) *Tribal Peoples and Economic Development: Ecologic Considerations* (World Bank, Washington, DC).
49. Treves A, Wallace RB (2006) Co-managing human-wildlife conflicts: A review. *Hum Dimens Wildl* 11:383–396.
50. Norton-Griffiths M (1996) Property rights and the marginal wildebeest: An economic analysis of wildlife conservation options in Kenya. *Biodivers Conserv* 5: 1557–1577.
51. Shyamsundar P, Kramer R (1997) Biodiversity conservation - at what cost? A study of households in the vicinity of Madagascar's Mantadia National Park. *Ambio* 26: 180–184.
52. Zabel A, Roe B (2009) *Performance Payments for Environmental Services: Lessons from Economic Theory on the Strength of Incentives in the Presence of Performance Risk and Performance Measure Distortion* (International Institute for Environment and Development, London).
53. Nistler C (2007) Seeing spots: The return of the jaguar. *PERC Reports* 25:10–14.
54. Zabel A, Holm-Müller K (2008) Conservation performance payments for carnivore conservation in Sweden. *Conserv Biol* 22:247–251.
55. Ferraro PJ, Simpson RD (2002) The cost-effectiveness of conservation payments. *Land Econ* 78:339–353.
56. Groom B, Palmer C (2009) *Environmental Services and Poverty Alleviation: Either, or, or Both?* (University College, London).
57. Wunder S, Engel S, Pagiola S (2008) Taking stock: A comparative analysis of payments for ecosystem services programs in developed and developing countries. *Ecol Econ* 65:834–852.
58. Hazzah L, Dolrenry S (2007) Coexisting with predators. *Sem* 577:21–27.
59. Macdonald DW, Mace GM, Rushton SP (2000) British mammals: is there a radical future? in *Priorities for the Conservation of Mammalian Diversity: Has the Panda Had Its Day?*, eds Entwistle A, Dunstone N (Cambridge Univ Press, Cambridge, UK), pp 175–205.
60. Macdonald DW (2000) Bartering biodiversity: what are the options? in *Economic Policy: Objectives, Instruments and Implementation*, ed Helm D (Oxford Univ Press, Oxford), pp 142–171.