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DESIGNING INTEGRATED CONSERVATION AND DEVELOPMENT PROJECTS (ICDPS): ILLEGAL HUNTING, WILDLIFE CONSERVATION AND THE WELFARE OF THE LOCAL PEOPLE

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Designing Integrated Conservation and Development Projects (ICDPs): Illegal hunting, wildlife conservation and the welfare of the local people

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Abstract:

This paper develops a bio-economic model to explore the effect on illegal hunting, wildlife conservation and human welfare of the most common instruments of existing ICDPs. It is demonstrated that stimulating working opportunities in the formal sector has the potential of promoting conservation, while money transfers and distribution of game meat to the local people fail, if not explicitly linked to the conservation objective. The analysis shows that such links, modelled as a risk of being excluded from the project if caught in illegal hunting, may be a more durable mean for ICDPs to reach its goal of improved wildlife conservation and human welfare. The model is illustrated by numerical calculations with data from Serengeti, Tanzania.

1. Introduction

1.1. Background

Integrated Conservation and Development Projects (ICDPs) are widely launched as the solution to the problem of biodiversity loss in developing countries. In sub-Saharan Africa, ICDPs are frequently designed to encourage conservation by reconciling the management of protected areas with the social and economic needs of the local people (see Kiss 1990, Barbier 1992, Brandon and Wells 1992, Wells and Brandon 1992, Barrett and Arcese 1995, Barrett and Arcese 1998, Songorwa 1999). Through benefit sharing it is expected that ICDPs will discourage poaching and promote economic development (see Kiss 1990 and Barbier 1992). The understanding is therefore that such a management scheme can improve the livelihood of rural communities without contributing to environmental degradation. There are several ways in which ICDPs can generate benefits for the local people, e.g. through revenue transfers from tourism, local job creation in the formal sector, stimulating increased productivity in the agricultural sector, and so forth. Benefit sharing is also obtainable through direct utilization of wildlife, such as harvesting quotas for the local communities and controlled culling operations. By providing such benefits, the ICDPs aspire to stimulate the local people to reduce wildlife exploitation (Brandon and Wells 1992, Wells and Brandon 1992, Gibson and Marks 1995, Songorwa 1999).

However, ICDPs have recently attracted attention because of the untested assumptions behind the projects. Brandon and Wells (1992) give a broad and instructive discussion of the design dilemmas of ICDPs and describe some of the trade-offs inherent in linking conservation and development. Experience shows that many existing projects lack a direct link between the hunting activity of the local people and the conservation objective. As pointed out by Kiss (1990) and Brandon and Wells (1992), without such a link it is difficult for the local people to realize that there is a purpose of improved conservation behind the benefits they receive. If worst comes to worst, they may regard the benefits as lump-sum transfers and carry on the exploitation activities as before. Both Kiss (1990) and Brandon and Wells (1992) stress the necessity of establishing such a connection.

The lack of a proper link in existing ICDPs is the point of departure for the present paper. The main purpose is to compare the performance of two different ICDP designs or regimes. The difference between the regimes is related to the implementation of one of the four ICDP tools of focus here. This tool is the benefit-sharing instrument which consists of distribution of game meat from controlled culling and income transfers from the tourism sector. In the first regime, an ICDP is implemented without an explicit link between the benefit transfers and the hunting activity of the local people. That is, there is no risk of being excluded from these benefits if caught in illegal hunting. This corresponds to Barrett and Arcese's model (1998) (see below) and is in line with the design of most existing ICDPs today (see Brandon and Wells 1992). In the second regime, the project designer implements a link by creating a continuous risk of being excluded from the benefit transfers if caught in illegal hunting. Then, if caught, the local people receive no benefits from the ICDP. There are, of course, other ways in which ICDPs can link the benefit transfers with the conservation objective. For instance, ICDPs may offer comprehensive training and education to the local people in order to make them realize that the magnitude of future transfers depends on the wildlife abundance – and consequently on their hunting activity – as more wildlife generates more income in tourism and opens for more extensive game culling. The link modelled here, however, is more direct and easier to implement because the performance of the project does not require that the local people behave in a self-enforcing and less myopic way.

Barrett and Arcese (1998) reveal possible unintended outcomes of benefit sharing for wildlife conservation. They present a bio-economic model with no explicit link between the conservation objective and the benefit-sharing instruments. The economic part of the model consists of a representative household for the rural population in western Serengeti in Tanzania which derives utility from consumption of game meat, agricultural output and leisure. It is also assumed that no market exists for game meat, meaning that the meat is used for household consumption. First, they demonstrate that money transfers from tourism may lead to a smaller degree of wildlife conservation. This is because the money transfers produce a positive income effect on game meat consumption. Second, they show that the conservation effect of game meat distribution from controlled culling is negative. This is because distribution of free game meat increases the real income of the households, which increases the total demand for game meat. Hence, the analysis of Barrett and Arcese (1998) gives reasons to question ICDPs that rely on money transfers and culling operations[1].

As already mentioned, the main focus of this paper is to analyse under what conditions, and for which design, ICDPs relying on benefit-sharing instruments can promote wildlife conservation and human welfare. Quite similar to Barrett and Arcese (1998), the analysis demonstrates that, in absence of a link between illegal hunting and the received transfers, as described above, benefit transfers will lead to a smaller degree of wildlife conservation. However, in contrast to Barrett and Arcese (1998), benefit sharing may promote wildlife conservation in presence of a link between the transfers and illegal hunting. It turns out that benefit transfers perform better if combined with more extensive use of guards and patrol units in the protected area. In this case, benefit sharing may also improve the economic conditions of the local community.

In addition to the design of the benefit-sharing strategies, the present paper also looks at the role of working opportunities in the formal sector, improved productivity in agriculture and, as mentioned, anti-poaching law enforcement. The wage rate in the formal sector and the productivity in agriculture are considered independent of whether the local people are caught in illegal hunting. This assumption seems reasonable because ICDPs cannot fully control the conditions in these sectors. In the analysis of anti-poaching law enforcement the focus is on increased use of guards and patrols, in order to improve the detection rate, and an increase in the fine level imposed on the local people if they are caught.

When it comes to agricultural policies, attempts to stimulate productivity improvements are repeatedly suggested in wildlife management (see Brown et al. 1993). It is believed that this will divert labour away from wildlife hunting to agricultural production. However, Lopez (1998) demonstrates that this argument may be false, depending on for what type of crop the productivity increases; i.e. land-intensive crop or labour-intensive crop. Using a static model with fixed land endowments and no labour market, he shows that an increased price for the land-intensive output is likely to reduce the labour demand for farming, and hence increase the resource extraction. Also Schulz and Skonhoft (1996) discuss agricultural productivity and its impact on resource extraction. Focusing on the conflict between land as an input agricultural production and land for wildlife habitat, they demonstrate that a higher return on agriculture increases the conversion of land and is therefore a threat to wildlife conservation (see also Skonhoft 1999).

Other contributors who question the importance of agricultural productivity are Bulte and van Soest (1999). Utilizing a dynamic model for a hunter-agrarian household, they demonstrate that the conservation effect of increased agricultural productivity is unclear and critically dependent on whether or not there exist markets for game meat and labour. With such markets present, the household solves the optimal effort in agriculture and hunting separately[2].

Consequently, there is no effect on wildlife exploitation of improved productivity in agriculture. However, with no markets present, they demonstrate that the conservation effect of productivity improvements is ambiguous. These analyses indicate that ICDPs promoting agricultural productivity should be implemented with care, especially when it comes to land use conflicts and regional conditions such as the functioning of markets.

The following analysis differs from the contributions quoted above in two important ways. First, while most of the authors referred to above limit their focus to benefit-sharing strategies and improved agricultural productivity, this paper also considers the impact of employment in formal sector and anti-poaching law enforcement. The main contribution of the paper is to suggest an ICDP design that will succeed in promoting wildlife conservation. As already mentioned, this involves an explicit link where the local people are excluded from the benefit transfers if caught in illegal hunting. Second, because ICDPs also aim at improving the economic conditions of the local people, the present paper extends the above contributions by exploring the welfare effect of the ICDP incentives.

1.2. Assumptions

This paper presents a bio-economic model of a hunter-agrarian community on the border of a protected area, i.e. a national park. The property rights to wildlife are held by the State which has appointed a park agency to manage the protected area. The local people have no legal rights to wildlife hunting, but the degree of anti-poaching law enforcement imposed by the park agency is not sufficient to eliminate illegal hunting and effectively protect the property rights of the State[3].

Throughout the analysis, the local people are considered the only active agent, while the park authority is passive (see also Milner-Gulland and Leader-Williams 1992). This means that the State instructs the benefit-sharing strategies and the law enforcement activities on the park manager and, hence, these activities are implemented as exogenous[4]. This is contrary to the analyses of Skonhoft (1995), Skonhoft (1998), and Skonhoft and Solstad (1998) where the game culling and the level of law enforcement are determined within the model. Following Barrett and Arcese (1998), it is further assumed that game meat is distributed freely to the local communities and, consequently, this activity does not generate income for the park manager. However, the park agency benefits from non-consumptive use of the wildlife, such as tourism. A fixed share of this income – pre-determined by the State – is transferred to the local people.

As in Barrett and Arcese (1998), Lopez (1998), and Bulte and van Soest (1999), it is assumed that illegal hunting is only performed by the local people living in the vicinity of the protected area. Poaching carried out by outsiders is therefore ignored. In addition to illegal hunting, the local people are involved in agricultural production and offered work opportunities in the formal sector, such as employment in the local industry and tourism. A market for labour is therefore present and this is in accordance with the general model of Bulte and van Soest (1999), while Barrett and Arcese (1998) and Lopez (1998) assume that no such market exists. In contrast, there exists no market for game meat which may be a result of high transaction costs (see e.g. Sadoulet and de Janvry 1995). With no market for game meat the local people's consumption is constrained by the transfers from the managed culls and the illegal offtake (see below, see also Barrett and Arcese (1998)).

The rest of the paper is organized as follows. The model is presented in section 2, while section 3 explores the conservation and welfare effects of ICDPs implemented without a link between the benefit sharing instruments and illegal hunting. That is, the local people receive the benefit transfers regardless of their involvement in illegal hunting. This regime is referred to as Regime I. In Regime II in section 4, the model is adjusted to investigate the performance of ICDPs where the local people face a risk of being excluded from the benefit transfers if caught in illegal hunting. Section 5 illustrates the theoretical model with a numerical example of the wildlife exploitation in Serengeti. The paper is closed by a discussion and concluding remarks in section 6.

2. The model

Consider a local community consisting of a homogeneous group of peasants living on the border of a protected area[5]. The local people produce two types of output; agricultural crops and game meat. The agricultural production is dependent on the amount of agricultural land, pesticides and fertiliser use, rainfall etc., as well as labour effort use. Following Barrett and Arcese (1998), Lopez (1998) and Bulte and van Soest (1999), all factors are fixed except for labour E_A. Then, the production function reads

(1) $A = A(E_A)$,

where output increases by a decreasing rate in effort, $A' > 0$ and $A'' \leq 0$.

The households produce game meat through illegal hunting of wildlife in the protected area. It is assumed that the wildlife offtake is a function of labour effort and the wildlife abundance, specified as

(2) $h = f(E_h)X$,

where E_h is effort directed towards hunting and *X* is the wildlife stock. The offtake increases by a decreasing rate in effort, $f' > 0$ and $f'' \leq 0$[6]. The degree of effort directed towards wildlife hunting is influenced by the fact that this activity is illegal. The probability of being caught in illegal hunting θ is given as

(3) $\theta = min[1, \delta E_h]$

θ increases with the hunting effort, but the probability of being caught cannot exceed 1 (see also Skonhoft and Solstad 1998). $\delta > 0$ is the marginal rate of detection, which reflects the productivity or the level of law enforcement activities carried out by the park manager. For a given hunting effort, more extensive enforcement use increases δ and, hence, θ increases. If caught in illegal hunting, the households are imposed a fixed fine *F*.

In addition to wildlife hunting and agricultural production, the local people have the opportunity to work in the formal sector (see section 1.2). Let *N* be the labour use in formal sector and *T* be the fixed available labour effort interpreted as the total human population living in the vicinity of the conservation area[7]. Then, the time constraint reads

(4) $E_h + E_A + N \leq T$

Throughout the analysis the time constraint is assumed to be binding, and hence, there is always a positive opportunity cost of labour use. As a result, a trade-off between effort in wildlife hunting and the legal activities is present.

The households derive utility from the consumption of agricultural output and game meat. There are two possible states in this model: either the local people will manage to escape the anti-poaching patrols with the probability $(1-\theta)$, or they will be caught with the probability θ. It is assumed that the decision problem of the local people is to maximize the expected utility given as

$$(5) \qquad EW = (1-\theta)\left[U(C_A^e)+V(C_G^e)\right]+\theta\left[U(C_A^c)+V(C_G^c)\right]$$

Here, superscript '*e*' denotes the resulting consumption levels if the local people manage to escape the patrol units, while superscript '*c*' denotes the consumption levels if caught in illegal hunting. In order to simplify the analysis, the expected utility is specified as separable in agricultural and game meat consumption, where $U'(\cdot)>0$ and $V'(\cdot)>0$. The magnitude of the second order derivatives of *U* and *V* reflects the local people's attitude towards risk. In general, the attitude towards risk depends on how wealthy the decision-maker is (see e.g. Dasgupta 1993, chapter 8). It is plausible that poor households would be more averse to accepting additional risk compared to relatively more wealthy agents, because the disadvantage of the risk, here represented by the monetary punishment, is particularly harsh for households who have little to fall back on. Because this analysis is related to poor communities in remote areas in developing countries, it is assumed that the local people are risk averse[8]. This means that the expected utility function is strictly concave in agricultural and game meat consumption, i.e. $U''(\cdot)<0$ and $V''(\cdot)<0$.

A trade-off in hunting effort is present in the expected utility function *(5)*. First, more hunting effort increases the consumption of game meat which, in turn, increases the utility for a given consumption of agricultural output and probability of being caught. However, more hunting effort reduces the income from formal employment which restricts the agricultural consumption. This works in the direction of reduced utility. In addition, the realized consumption levels are, in general, higher if the local people manage to escape the patrol units, i.e. $C_A^e \geq C_A^c$ and $C_G^e \geq C_G^c$ (see below). Therefore, as more hunting effort increases the probability of being caught it reduces the expected utility level. The local people must consider these trade-offs when determining the allocation of labour effort between agricultural production, wildlife hunting, and employment in the formal sector.

The next step is to specify the prevailing constraints on consumption if the local people manage to escape the patrol units. First, the consumption of game meat consists of the illegal offtake and legal game meat distributed from the managed culls. In the following, these are considered homogenous. The extent of the game meat distribution is set as a fraction $m > 0$ of the wildlife stock *X*[9]. It is assumed that the local community in consideration is the only community to receive game meat from the culling program, which means that the whole amount *mX* is transferred to this community[10]. Because there is no market for game meat, the consumption of meat if not caught in illegal hunting is constrained as in *(6)*[11].

$$(6) \qquad C_G^e = f(E_h)X + mX$$

The consumption of agricultural output if not caught in illegal hunting is constrained by the level of agricultural production, income from formal employment, and the income transfers from tourism. The latter is set as a fixed fraction $\mu \in [0, 1]$ of the net income in the tourism sector *S(X)*. It is assumed that *S(X)* increases with the wildlife density as the number of tourists increases, but at a decreasing rate $S' > 0$, $S'' \leq 0$ (see Bulte and van Kooten 1996). Employment in formal activities is paid by the exogenous wage ω. Let P_A be the unit price of agricultural output. Then, if the local people manage to escape the patrol units, the consumption expenditure on agricultural output equals $P_A C_A^e = P_A A(E_A) + \mu S(X) + \omega N$. Solving this equation with respect to C_A^e yields

$$(7) \qquad C_A^e = A(E_A) + \mu S(X) / P_A + \omega N / P_A$$

In general $C_A^e > A(E_A)$ which means that the local people will buy excess agricultural food on the market if they escape the patrol units. However, in absence of formal employment and an ICDP program (i.e. $N = \mu = 0$) the constraint in *(7)* reads $C_A^e = A(E_A)$. In this case, the agricultural consumption is constrained by the production level in this community.

The prevailing constraints on agricultural and game meat consumption if caught in illegal hunting are strictly dependent on the design of the ICDP. Sections 3 and 4 below outline in detail the resulting constraints for the respective regimes. The final step in this section is to present the population dynamics of wildlife. As already noted, the local peasants are the only agents involved in illegal hunting, meaning that their hunting constitutes the total illegal offtake. The natural growth of the population is specified as logistic, while the stock shrinks according to illegal hunting and managed culling, as given in equation *(8)*.

(8) $$dX/dt = rX(1 - X/K) - f(E_h)X - mX$$

Here, r is the intrinsic growth rate and K is the carrying capacity of the protected area. The total harvest equals the sum of the illegal offtake $f(E_h)X$, and the managed harvest mX. The ecological equilibrium is defined by a constant wildlife stock over time. Solving for X at $dX/dt = 0$ yields $X = (r - f(E_h) - m)K/r$, so that wildlife abundance is reduced by m and E_h. To obtain $X \geq 0$, the man made mortality must be restricted by $f(E_h) + m \leq r$ [12].

Before we turn to the specific ICDP regimes, we need to establish how the local people adapt to the ecology. As already noted, the State has the property rights to wildlife, while hunting performed by the local people is illegal. The local people experience, through the property rights scheme and anti-poaching law enforcement, a continuing risk of being effectively denied access to hunting. It is therefore assumed that their behaviour is based on short-term expected utility maximization and hence, they do not take the stock density into account when maximizing expected utility. Technically, this means that the local people treat the stock density as an exogenous variable and this corresponds to one of Smith's models (1975). See also Lopez (1998), Barrett and Arcese (1998), and Skonhoft and Solstad (1998).

3. Regime I

In this regime, the ICDP manager transfers money from tourism and game meat to the local people independent of whether they are caught in illegal hunting. Hence, if caught in illegal hunting, the resulting budget available for agricultural consumption is lowered by the imposed fine F only. The constraint on agricultural consumption is therefore given by

(9) $$C_A^c = A(E_A) + \mu S(X)/P_A + \omega N/P_A - F/P_A$$

In the absence of formal employment and an ICDP program, this constraint reads $C_A^c = A(E_A) - F / P_A$. This means that the local people must sell agricultural output to finance the imposed fine. However, in the presence of formal employment and an ICDP, the local people may purchase excess crops on the market as long as the additional income exceeds the imposed fine.

The next step is to present the resulting constraint on game meat consumption if caught in illegal hunting. In line with Skonhoft and Solstad (1998), it is assumed that the local people keep the illegal meat if caught. That is, they manage to hide the meat from the patrol units. In addition, as already mentioned, they will receive game meat from the culling program even if they are caught poaching. The resulting constraint on game meat consumption if caught therefore coincides with the prevailing constraint if they manage to escape in *(6)*, i.e. $C_G^c = C_G^e$.

Because the game meat consumption is independent of whether the local people are caught in illegal hunting, i.e. $C_G^c = C_G^e$, the expected utility function reads $EW = (1-\theta)U(C_A^e) + \theta U(C_A^c) + V(C_G)$, where the superscript on C_G is omitted. Substituting the consumption constraints *(6)*, *(7)* and *(9)*, together with constraints *(3*) and *(4)*, into this expression gives the expected utility function as $EW = (1-\delta E_h)\{U(A(E_A) + \mu S(X)/P_A + \omega(T - E_h - E_A)/P_A)\}$ $+ \delta E_h\{U(A(E_A) + \mu S(X)/P_A + \omega(T - E_h - E_A)/P_A - F/P_A)\} + V(f(E_h)X + mX)$. The local people must decide upon the optimal effort use in hunting E_h and agricultural production E_A in order to maximize its expected utility. Because the local people treat the wildlife stock as exogenous, they impose no shadow price on wildlife. The Kuhn-Tucker first order maximum conditions are then given in *(10)*-*(11)*.

(10) $$\left[(1-\delta E_h)U'(C_A^e) + \delta E_h U'(C_A^c)\right](A'(E_A) - \omega / P_A) \leq 0\,;\ = 0 \text{ if } E_A > 0$$

(11) $$V'(C_G)f'(E_h)X - \left[(1-\delta E_h)U'(C_A^e) + \delta E_h U'(C_A^c)\right]\omega / P_A$$
$$-\delta\left[U(C_A^e) - U(C_A^c)\right] \leq 0\,;\ = 0 \text{ if } E_h > 0$$

Equation *(10)* gives the optimal effort use in agricultural production E_A^I, where superscript *I* denotes the case of Regime I. In what follows, an interior solution for E_A (> 0) is assumed to hold, so that the first order condition *(10)* holds with equality. The first parenthesis is positive and, hence, this condition reads $A'(E_A) - \omega / P_A = 0$. This means that effort should be directed towards agricultural production until the value of the marginal product equals the wage rate in formal employment. Therefore, the agricultural productivity, the price of agricultural output, and the wage rate in formal sector are the only factors determining the optimal effort use in agricultural production. Hence, effort is allocated to agriculture independent of the amount of effort directed towards hunting and formal employment. This result is identical to what is demonstrated by Bulte and van Soest (1999).

Equation *(11)* gives the first order condition with respect to the hunting effort E_h^I. The first term on the left hand side reflects the marginal expected utility from hunting where more effort in illegal hunting increases the expected utility due to increased game meat consumption. The second and third terms give the marginal cost or disutility from hunting. The second term implies that more effort use in illegal hunting reduces the time in formal employment and, consequently, reduces the budget available for consumption of agricultural commodities. In addition, as seen in the third term, more hunting effort increases the probability of being caught, which reduces the expected utility for a given consumption bundle. The local people will refrain from illegal hunting, i.e. $E_h^I = 0$, if the marginal disutility exceeds the marginal utility. This will be the case if the fraction of meat distributed to the community, the fine level, and the marginal probability of being detected are ‘high’. However, because the intention of ICDP is to promote wildlife conservation by stimulating the local people to reduce the poaching, the case of no illegal hunting will not be considered in the following. Instead, it is assumed that an interior solution for E_h exists, where the local people divert effort to illegal hunting until the marginal utility of hunting equals the marginal disutility.

Having solved for E_A^I through *(10)*, E_h^I and X^I follow simultaneously in *(8)* (with $dX/dt = 0$) and *(11)*, while N^I is determined in *(4)*. The resulting consumption of game meat and the agricultural consumption, depending on whether the local people are caught in illegal hunting, follows from *(6)*, and *(7)* or *(9)*, respectively.

The next step is to analyse how the benefit-sharing instruments of ICDP influence the hunting decision of the local people, wildlife conservation and local welfare. The comparative static results in ecological equilibrium are derived from the derivatives of *(8)* (with $dX/dt = 0$) and *(11)*. The welfare effect follows from *(5)* when taking into account the impact of a changing wildlife stock[13]. See Appendix 1. Consider first the effect of an increase in the amount of game meat distributed from the managed culls to the local people, i.e. m increases. The direct effect on wildlife conservation is negative. The indirect effect works through a changing effort use in illegal hunting. Because there exists no external market where the local people can sell excess game meat, the only option is to consume the legal meat domestically (or within the community). The local people will therefore substitute illegal meat for distributed meat and reduce their effort in illegal hunting. Therefore, the indirect effect of game culling works in the direction of a higher degree of wildlife conservation. It can be demonstrated, however, that the direct connection is the dominating effect. Hence, while this policy fulfils the aim of reducing illegal hunting, the aggregate offtake increases and this lowers the degree of wildlife conservation. This result is in line with the findings of Barrett and Arcese (1998). By providing game meat to the local people, the management authority contributes to increased pressure on the wildlife stock. The wildlife is therefore more protected without this kind of interference from the authorities[14].

Second, an increase in the income from tourism, i.e. μ increases, leads to an increase in illegal hunting and a smaller wildlife stock. The mechanism works as follows: money transfers which are received for certain increase the level of income in both of the states 'escape' and 'caught' (see section 2). This has two positive and quite similar effects on the hunting effort. First, it enables the local people to carry more risk. That is, they pay less attention to the probability of being caught when deciding upon the optimal use of effort in illegal hunting. Second, an increased certain income makes the local people less responsive to the fact that increased hunting effort reduces the income in formal employment. Both effects reduce the marginal cost of hunting and stimulate increased hunting effort. Consequently, certain income transfers reduce the degree of wildlife conservation[15]. Although the mechanism is somehow different, this result is in accordance with both Barrett and Arcese (1998) and Skonhoft (1998), and suggests that ICDPs relying on money transfers fail to conserve wildlife.

Third, the effect of a positive shift in the wage rate ω in formal employment is generally unclear. All else equal, a higher wage level increases the certain income level. Quite similar to increased money transfers from tourism, this enables the local people to carry more risk and to draw back workers from the formal sector. Hence, this effect works in the direction of increased hunting effort. Compared to the money transfers from tourism, the difference lies in the fact that an increased wage rate in formal employment has a direct negative effect on hunting as it increases the alternative cost of effort use in this activity. The total effect is therefore unclear. However, if the latter effect dominates, then a higher wage rate will promote wildlife conservation. This will be the case if the employment in formal sector is initially 'low'. See also Table 1. In this case, a higher payment in formal sector will also improve the economic conditions of the local people. The conclusion is therefore that ICDPs relying on work opportunities in the formal sector may fulfil the aim of promoting both wildlife conservation and local welfare.

Fourth, improved agricultural productivity or a higher price of agricultural output P_A has an ambiguous effect on hunting effort and wildlife conservation. See Table 1. The effect is strictly dependent on the fine level. Recall from equation *(9)* that when the fine level is 'low', the local people will buy food on the market to supplement their consumption in both states. In this case, the effect of a higher agricultural price is ambiguous. On the other hand, when faced with a 'high' fine level the local people will sell excess agricultural output on the market in order to finance the penalty if caught in illegal hunting. That is, the local people are net producers of agricultural output in this state. Then, a higher agricultural price increases the level of income if caught in illegal hunting which, in turn, enables the local people to carry more risk. This effect works in the direction of increased hunting effort. There is also an additional effect present, working through the state where the local people manage to escape. In this state, they are net consumers of agricultural commodities and, consequently, a higher agricultural price reduces the income level and their ability to carry risk. It turns out that if fine level and the probability of being caught in illegal hunting are 'high', then the first effect dominates and the local people will increase the illegal hunting. See also Table 1. Hence, in situations of a high level of anti-poaching law enforcement, policies which stimulates a high agricultural return will lower the degree of wildlife conservation. This result is contrary to the arguments of Brown et al. (1993) and the findings of Skonhoft and Solstad (1998)[16].

The final policy option is to increase the degree of anti-poaching law enforcement in order to increase the marginal cost of illegal hunting. This policy includes more extensive use of guards and patrols, which increases the probability of being caught, and a higher fine level. Obviously, such attempts will promote wildlife conservation. However, the effect on the welfare of the local people is ambiguous. See Table 1. While the direct welfare effect is negative, there is a positive indirect effect working through a changing wildlife stock, as more wildlife increases the transfers of game meat and money from the tourism sector. If the latter effect dominates, law enforcement will promote wildlife conservation and improve the welfare of the local people.

4. Regime II

The objective so far has been to investigate the impact on wildlife conservation and the welfare of the local people of the most common instruments of existing ICDPs. One of these instruments is benefit-sharing which consists of distribution of game meat and income transfers from tourism. Most existing ICDPs lack a proper link between the benefit transfers and illegal hunting, and section 3 demonstrated that transfers relying on this design do not have the potential of promoting wildlife conservation. Instead, it is clear that working opportunities in the formal sector provide, under given conditions, the most promising way of encouraging wildlife conservation and local welfare.

Despite the fact that game meat distribution and income transfers fail in meeting the aims of today's ICDPs, they are launched as having the potential to curtail illegal hunting and promote wildlife conservation. Therefore, the objective of this section is to look at an alternative design of the benefit-sharing strategies in order to reach the aim of integrated wildlife conservation and improved local welfare. In section 3 it was shown that a higher fine level reduces the illegal hunting pressure and promotes wildlife conservation. In addition, this policy may improve the economic conditions of the local people if the benefit transfers are 'high'. This suggests that one promising strategy may be to increase the costs of being caught in illegal hunting. One possible way is to attach an uncertainty to the benefit transfers so that participation in benefit sharing becomes conditioned by whether the local people are caught in illegal hunting. Then, in contrast to section 3, the transfers are no longer certain; the local people receive them if they manage to escape the patrol units, while they are denied transfers if they get caught. This section presents an ICDP design based on such a link between participation in benefit sharing and the imposed punishment if caught in illegal hunting.

Compared to Regime I, the present ICDP design restricts the resulting consumption possibilities of the local people if they are caught in illegal hunting. First, the local people receive no money transfers from tourism and, hence, $\mu = 0$. The resulting constraint on agricultural consumption yields

(12) $$C_A^c = A(E_A) + \omega N / P_A - F / P_A$$

Second, the local people are excluded from the game meat distribution program if they get caught in illegal hunting. Then, the constraint on game meat consumption equals[17]

(13) $$C_G^c = f(E_h)X$$

When inserting the consumption constraints in *(6)*, *(7)*, *(12)*, and *(13)*, together with the probability of being caught in equation *(3)* and the time constraint in *(4)*, the expected utility follows as
$EW = (1-\delta E_h)\left[U((A(E_A) + \mu S(X)/P_A + \omega(T - E_A - E_h)/P_A) + V(f(E_h)X + mX)\right]$
$+ \delta E_h\left[U((A(E_A) + \omega(T - E_A - E_h)/P_A - F/P_A) + V(f(E_h)X)\right]$. Again, the decision problem of the local people is to decide upon the optimal effort directed towards illegal hunting E_h and agricultural production E_A in order to maximize the expected utility. With an interior solution present (see section 3), the first order conditions for maximum are given in *(14)*-*(15)*.

(14) $$\left[(1-\delta E_h)U'(C_A^e) + \delta E_h U'(C_A^c)\right]\left(A'(E_A) - \omega / P_A\right) = 0$$

(15) $$\left[(1-\delta E_h)V'(C_G^e) + \delta E_h V'(C_G^c)\right]f'(E_h)X - \left[(1-\delta E_h)U'(C_A^e) + \delta E_h U'(C_A^c)\right]\omega / P_A$$
$$- \delta\left[U(C_A^e) + V(C_G^e) - U(C_A^c) - V(C_G^c)\right] = 0$$

Equation *(14)* gives the optimal effort use in agricultural production E_A^{II}, where superscript *II* denotes Regime II. Again, the first parenthesis is positive, so that the first order condition reads $A'(E_A) - \omega / P_A = 0$. Hence, the presence of a link does not alter the result that the optimal effort use in agriculture is determined by the price and productivity in agriculture and the wage rate in formal sector, but independent of the effort use in hunting and formal employment.

Having solved for E_A^{II} in *(14)*, E_h^{II} and X^{II} follow simultaneously in *(15)* and *(8)* (with $dX / dt = 0$). The first order condition in *(15)* states that effort should be directed towards hunting until the marginal benefit (i.e. the first term) equals the marginal cost (i.e. the second and third term). For fixed parameter values, $(C_G^c)^{II} < (C_G^c)^I$ and $(C_A^c)^{II} < (C_A^c)^I$. Consequently, the first order condition in *(15)* differs in general from *(11)*. In order to compare the regimes, consider first the impact of a link on the income transfers from tourism. Because there is an uncertainty attached to the income transfers in Regime II, the realized consumption level of agricultural output if caught in illegal hunting is lower than in Regime I. Therefore, as seen from the second term in *(15)*, a link on the income transfers will increase the marginal cost of hunting and work in the direction of reduced hunting effort. There is an additional effect working through the fact that this link increases the gap between the consumption levels C_A^e and C_A^c. The resulting loss if being caught in illegal hunting is therefore higher in Regime II, which strengthens the negative impact on hunting effort. This means that ICDPs relying on a link between income transfers and the costs of being caught in illegal hunting will produce a higher degree of wildlife conservation.

Consider now the effect on illegal hunting of implementing a link on the game meat distribution. First, compared to Regime I the realized consumption level of game meat if caught is now lower. This increases the marginal expected utility of hunting and leads the local people to increase their hunting effort in order to compensate for the uncertainty of the transfers of game meat. The second effect works through the fact that this link increases the gap between consumption levels C_G^e and C_G^c. The loss resulting from being caught in illegal hunting is therefore higher in Regime II. Hence, this leads towards reduced hunting effort (see the third term in *(15)*). The total effect on hunting effort and wildlife conservation of a link on game meat distribution is therefore unclear. The numerical analysis in section 5 demonstrates under which conditions ICDPs relying on such a link will perform better than the ICDP design of today.

The next step is to investigate the effect on wildlife conservation and the welfare of the local people of increased transfers of game meat and income from the tourism sector. The comparative static results are derived from the derivatives of *(8)* (with $dX/dt = 0$), *(15)*, and *(5)* (see Appendix 1)[18]. First, consider the impact of increased game meat distribution m. In the same way as shown in section 3, the direct effect on hunting effort is negative as the local people substitute illegal meat for distributed meat in consumption. In the present scenario there is an additional negative effect working through the increased cost of being caught in illegal hunting. As a result, the effect on hunting effort is negative and stronger compared to Regime I. Increased distribution of game meat may therefore promote wildlife conservation. If this is the case, this policy will also succeed in improving the welfare of the local people. The conclusion is therefore that transfers of game meat have the potential of encouraging both conservation and welfare if properly linked to the cost of being caught in illegal hunting.

Table 1 about here

The effect on hunting effort in Regime II of increased money transfers from tourism is ambiguous. The positive effect is the same as discussed for Regime I in section 3. However, creating a link between the money transfers and the involvement in illegal hunting increases the marginal cost of being caught. This additional effect works in the direction of reduced hunting effort. The total effect on illegal hunting and wildlife conservation is therefore unclear. However, as seen from Table 1, money transfers may promote wildlife conservation if combined with policies which increase the probability of being caught in illegal hunting. In this case, income transfers may also improve the welfare of the local people. The remaining comparative static results are reported in Table 1[19].

5. Numerical analysis

The theoretical reasoning will now be illustrated by data which fits the wildebeest exploitation in the Serengeti-Mara ecosystem. This ecosystem is positioned on the border between Tanzania and Kenya and contains the world's largest ungulate herds (Sinclair and Arcese 1995, Barrett and Arcese 1998). The Serengeti National Park is a part of it, and compromises more than half of the ecosystem's land area (Barrett and Arcese 1998). The outer area of focus in the numerical analysis is the border area along the western corridor of the park where most of the poaching takes place. This area has experienced a rapid growth in human settlement (Campbell and Hofer 1995, Barrett and Arcese 1998) which coincides with a marked increase in the number of poachers arrested in the park (Arcese et al. 1995). As a result, Sinclair (1995, p. 24) states that "the illegal killing of the migrant ungulates by poachers is potentially the most serious threat to the Serengeti system".

The local people living on the western border of the park are mainly agro-pastoralists (Kauzeni and Kiwasila 1994). In addition, a survey conducted in Bunda and Serengeti District in 2001 predicts that almost 30 per cent of the households in this area are involved in illegal hunting (Johannesen 2002). Hunting in the protected area is illegal, i.e. there are no local property rights to wildlife. However, local people in western Serengeti benefit from the existing ICDP in the area, namely the Serengeti Regional Conservation Project. This project was implemented during 1993/1994 and aims to improve wildlife conservation mainly through distribution of game meat from the managed harvest of wild ungulates (see Barrett and Arcese 1998 and Rugumayo 1999). In addition, a revenue-sharing programme exists for one village in Serengeti District, under which the village receives money transfers from tourism activities established within the village area[20]. These benefit-sharing strategies are not subject to any risk of being expelled from the transfers as discussed in section 4. The current management regime in Serengeti is therefore characterised as an ICDP of Regime I.

The economic and ecological parts of the model are specified at the scale of one km^2 and one year. This means that the simulation results below report the wildlife density, that is, the number of animals per km^2. The closer definitions of the protected area and the outer area are found in Appendix 2. The baseline values for transfers, anti-poaching law enforcement, ecological data, and data for crop production and hunting used in the simulations are derived from the model of Regime I and also presented here. As demonstrated above, the conservation effect of money transfers and game meat distribution depend critically on the design of the benefit-sharing scheme. Because of the unclear effects, the coefficients m and μ, as well as ω, will be varied throughout the simulations.

Table 2 demonstrates how wildlife abundance varies with the culling coefficient m under the two regimes. The first column reports the results in Regime I, while the others give the results in Regime II when there is a link related to game meat distribution only (second column) and in the case where there also is a link to the income transfers from tourism (third column). In baseline $m = 0.0002$, and, consequently, wildlife density is $X^I = 50$ and $EW^I = 185$. As demonstrated in the theoretical analysis, increased legal offtake reduces the degree of wildlife conservation in this scenario. Compared to the baseline regime, the degree of wildlife conservation is not affected by introducing a link between involvement in illegal hunting and the benefit transfers. This is because the current transfers generate such a small amount of legal meat and income so that, all else equal, the expected cost of being caught only just increases when a risk of being expelled from the benefit-sharing programme is created. On the other hand, we see that a ‘high’ culling rate is sufficient to ensure that a link on game meat distribution will promote both wildlife conservation and local welfare. In fact, this is the case for a culling rate up to 9 per cent of the wildlife stock. Hence, in this range, the reduction in illegal hunting more than offsets the legal offtake. Contrary to Barrett and Arcese (1998), this indicates that the culling programme may succeed in promoting both wildlife conservation and local welfare if the distribution of meat is properly linked to the illegal hunting. However, if the culling rate exceeds 9 per cent, the degree of conservation reduces with a higher culling rate.

Table 2 about here

The simulations show, for both regimes, that the degree of wildlife conservation varies slightly with the money transfers from the tourism sector (see Appendix 2, Table A2). This means that the risk of being excluded from the money transfers cannot conquer the effect working through an increased expected income. Consequently, as seen in Table 2, there is no additional conservation effect of linking both benefit transfers to the illegal hunting. This suggests that a link on game meat distribution combined with a higher culling rate is a more promising strategy in order to fulfil the aim of a higher degree of wildlife conservation and improved welfare for the local people.

Let us turn to the wage rate in the formal sector. The theoretical analysis of Regime I revealed an ambiguous relationship between wildlife conservation and the wage rate ω. The numerical analysis discloses, however, a positive relationship. See Table 3. This means that the increased alternative cost of hunting is the dominating effect. Consequently, subsidies which stimulate increased wage rate in formal employment will promote both wildlife conservation and the welfare of the local people.

Table 3 about here

As discussed in the theoretical analysis of Regime I in section 3, a higher fine level may increase the degree of wildlife conservation without deteriorating the economic conditions of the local people. This will be the case if the conservation effect is relatively strong, so that the local community experiences a net gain due to increased transfers of game meat and money from the tourism sector. Table 4 demonstrates that the welfare is barely sensitive to a changing fine level. In fact, a double fine will increase the wildlife stock and leave local welfare unchanged.

Table 4 about here

6. Discussion and conclusion

The attempt of wildlife ICDPs is to link conservation in protected areas to economic development in the surrounding communities. However, many of the existing ICDPs have experienced difficulties which may be traced to the specific design of the projects (see Brandon and Wells 1992, Wells and Brandon 1992, Barrett and Arcese 1995, Gibson and Marks 1995). The central contribution of this exercise is to highlight some possible pitfalls, and to clarify in what way the management design is crucial for the success of ICDPs. In order to do so, this paper presents a hunter-agrarian community located on the periphery of a protected area. Hunting performed by the local people is illegal, but the law enforcement imposed by the park manager is not sufficient to eliminate the illegal hunting. Markets exist for labour and agricultural commodities, while no market is present for game meat.

The theoretical model specifies two alternative ICDP designs for benefit transfers, i.e. distribution of game meat from managed culling and transfers of income from the tourism sector. In the first regime, the project manager fails to link the benefit transfers to the illegal hunting. Consequently, the local people receive game meat and money from tourism independent of whether they get caught in illegal hunting. This regime is in accordance with most of the existing ICDPs. In the second regime the project manager imposes on the local people a continuous risk of being expelled from the benefit transfers if caught in illegal hunting. Hence, in addition to the risk of receiving a monetary fine, there is also a risk of being denied benefit transfers.

It is demonstrated that the success of benefit sharing is conditional on the ICDP design. A benefit-sharing scheme implemented without a proper link to illegal hunting is less likely to succeed in gaining wildlife conservation. In fact, it turns out that both game meat distribution and money transfers from tourism will contribute to wildlife degradation in this regime. Transfers of game meat fail because the reduction in illegal hunting is not sufficient to offset increased culling. Money transfers from tourism fail because a higher level of the certain income enables the local people to carry more risk and makes them less dependent on the income from formal employment.

In order for benefit sharing to succeed, this analysis shows that there must be a risk for the local people of being expelled from the transfers if they get caught in illegal hunting. If such a risk is present, distribution of game meat and money transfers may succeed in promoting both wildlife conservation and human welfare. These results are in contrast to the conclusion of Barrett and Arcese (1998). In the case of Serengeti we have seen that a link on game meat distribution combined with a higher culling rate leads to a higher degree of wildlife conservation and improved economic conditions of the local people.

Another important result of this study is that a higher return from formal employment may promote wildlife conservation. As long as the effect working through an increased alternative cost of hunting is relatively strong, the local people will shift the allocation of labour from illegal hunting to formal employment. This will be the case in areas with limited opportunities for formal employment. For the case of Serengeti we have seen that a higher wage rate in formal employment reduces the pressure on wildlife and improves the livelihood of the local people.

The general conclusion of this analysis is that work should be done in order to design some type of explicit agreement over the benefit-sharing instruments between the management authorities and the local people. This agreement must specify the rights and duties of the respective parties and must be supported by enforceable penalties that provide enough incentives for the parties to comply. However, in practice, designing such contracts may be difficult, especially in poor African countries where the local people lack resources or power to secure their interests. Still, ICDP projects need to let go of the assumption that transfers and support alone will make people who live in periphery areas refrain from illegal hunting in absence of sufficient anti-poaching law enforcement and penalties (see also Wells and

Brandon 1992). Projects partly depending on guard patrols and penalties are not inconsistent with the ICDP concept if combined with attempts to improve the welfare of the local people.

Appendix 1

1. Regime I

In Regime I, where there is no link between benefit transfers and involvement in illegal hunting, the effect on hunting effort and wildlife conservation of altering the management instruments are found by taking the total differential of *(8)* (with dX/dt = 0) and *(11)*. In the following, we specify $U(C_A) = k_A C_A^{\alpha}$ and $V(C_G) = k_G C_G^{\beta}$, where $k_i > 0$ $i = A, G$, $0 < \alpha \leq 1$ and $0 < \beta \leq 1$. For risk-averse poachers $\alpha < 1$ and $\beta < 1$. The differential is given in *(A1)* where λ_{E_h} denotes the derivative of *(11)* with respect to E_h, λ_X the derivative of *(11)* with respect to X etc.

(A1)

$$\begin{bmatrix} 1 & f'(E_h^I)K/r \\ \lambda_X & \lambda_{E_h} \end{bmatrix} \begin{bmatrix} dX^I \\ dE_h^I \end{bmatrix} = \begin{bmatrix} -K/r \\ \lambda_m \end{bmatrix} dm + \begin{bmatrix} 0 \\ \lambda_\mu \end{bmatrix} d\mu$$

$$+ \begin{bmatrix} 0 \\ \lambda_\omega \end{bmatrix} d\omega + \begin{bmatrix} 0 \\ \lambda_{P_A} \end{bmatrix} dP_A + \begin{bmatrix} 0 \\ \lambda_\delta \end{bmatrix} d\delta + \begin{bmatrix} 0 \\ \lambda_F \end{bmatrix} dF$$

The sign of $\lambda_{E_h} = \beta(\beta-1)k_G C_G^{\beta-2}\left[f'(E_h)X\right]^2 + \beta k_G C_G^{\beta-1} f''(E_h)X^2$

$+\alpha(\alpha-1)k_A\left[(1-\delta E_h)(C_A^e)^{\alpha-2} + \delta E_h (C_A^c)^{\alpha-2}\right](\omega/P_A)^2 + 2\delta\alpha k_A\left[(C_A^e)^{\alpha-1} - (C_A^c)^{\alpha-1}\right]\omega/P_A$ is negative, while the sign of

$$\lambda_X = \beta^2 k_G C_G^{\beta-1} f'(E_h) - \alpha(\alpha-1)k_A\left[(1-\delta E_h)(C_A^e)^{\alpha-2} + \delta E_h (C_A^c)^{\alpha-2}\right]\omega\mu S'(X)/P_A^2$$
$$-\delta\alpha k_A\left[(C_A^e)^{\alpha-1} - (C_A^c)^{\alpha-1}\right]\mu S'(X)/P_A$$

is positive. The determinant of the system, $\lambda_{E_h} - \lambda_X f'(E_h)K/r$, is therefore negative.

$\lambda_m = \beta(1-\beta)k_G C_G^{\beta-2} f'(E_h)X^2 > 0$,

$\lambda_\mu = \alpha(\alpha-1)k_A\left[(1-\delta E_h)(C_A^e)^{\alpha-2} + \delta E_h (C_A^c)^{\alpha-2}\right]\omega S(X)/P_A^2$

$+\delta\alpha k_A\left[(C_A^e)^{\alpha-1} - (C_A^c)^{\alpha-1}\right]S(X)/P_A < 0$. The signs of

$\lambda_\omega = \alpha(\alpha-1)k_A\left[(1-\delta E_h)(C_A^e)^{\alpha-2} + \delta E_h (C_A^c)^{\alpha-2}\right]\omega N/P_A^2$

$+\alpha k_A\left\{\left[(1-\delta(E_h-N)\right](C_A^e)^{\alpha-1} + \delta(E_h-N)(C_A^c)^{\alpha-1}\right\}/P_A$ and

$$\lambda_{P_A} = \alpha(\alpha-1)k_A\left[(1-\delta E_h)(C_A^e)^{\alpha-2}(A(E_A) - C_A^e) + \delta E_h (C_A^c)^{\alpha-2}(A(E_A) - C_A^c)\right]\omega/P_A^2$$
$$-\alpha k_A\left[(1-\delta E_h)(C_A^e)^{\alpha-1} + \delta E_h (C_A^c)^{\alpha-1}\right]\omega/P_A^2$$

$+\delta\alpha k_A\left[(C_A^e)^{\alpha-1}(A(E_A)-C_A^e)-(C_A^c)^{\alpha-1}(A(E_A)-C_A^c)\right]/P_A$ are unclear. Finally, the signs of $\lambda_\delta = -E_h\alpha k_A\left[(C_A^e)^{\alpha-1}-(C_A^c)^{\alpha-1}\right]\omega/P_A + k_A\left[(C_A^e)^{\alpha}-(C_A^c)^{\alpha}\right]$ and $\lambda_F = -\delta E_h\alpha(\alpha-1)k_A(C_A^c)^{\alpha-2}\omega/P_A^2 + \delta\alpha k_A(C_A^c)^{\alpha-1}/P_A$ are positive.

The welfare effect

Recall from the main text that the local people treat the wildlife stock as exogenous when deciding upon the optimal allocation of effort. When investigating the impact on local welfare, however, we must take into account the effect working through a changing wildlife stock. The total effect on local welfare is found by taking the differential of *(5)*. This is given in equation *(A2)*.

(A2)
$$\begin{aligned} dEW = &\left\{\alpha k_A\left[(1-\delta E_h)(C_A^e)^{\alpha-1}+\delta E_h(C_A^c)^{\alpha-1}\right]\mu S'(X)/P_A \right.\\ &\left. +\beta k_G C_G{}^{\beta-1}(f(E_h)+m)\right\}dX + \beta k_G(C_G)^{\beta-1}Xdm \\ &+\alpha k_A\left[(1-\delta E_h)(C_A^e)^{\alpha-1}+\delta E_h(C_A^c)^{\alpha-1}\right](S(X)/P_A)d\mu \\ &+\alpha k_A\left[(1-\delta E_h)(C_A^e)^{\alpha-1}+\delta E_h(C_A^c)^{\alpha-1}\right](N/P_A)d\omega \\ &+(\alpha k_A/P_A)\left[(1-\delta E_h)(C_A^e)^{\alpha-1}(A(E_A)-C_A^e)+\delta E_h(C_A^c)^{\alpha-1}(A(E_A)-C_A^c)\right]dP_A \\ &-E_h k_A\left[(C_A^e)^{\alpha}-(C_A^c)^{\alpha}\right]d\delta - (\delta E_h\alpha k_A(C_A^c)^{\alpha-1}/P_A)dF \end{aligned}$$

Here, $dEW/dm = \beta k_G(C_G)^{\beta-1}X + \left\{\alpha k_A\left[(1-\delta E_h)(C_A^e)^{\alpha-1}+\delta E_h(C_A^c)^{\alpha-1}\right]\mu S'(X)/P_A + \beta k_G C_G{}^{\beta-1}(f(E_h)+m)\right\}dX/dm$, where *dX/dm* is given from equation *(A1)*. The same procedure is used in order to derive the welfare effect of the remaining exogenous variables.

2. Regime II

In the present of a link the effects are found by taking the total differential of *(8)* (with *dX/dt* = 0) and *(15)* as in *(A3)*.

(A3)
$$\begin{bmatrix} 1 & f'(E_h)K/r \\ \lambda_X & \lambda_{E_h} \end{bmatrix}\begin{bmatrix} dX \\ dE_h \end{bmatrix} = \begin{bmatrix} -K/r \\ \lambda_m \end{bmatrix}dm + \begin{bmatrix} 0 \\ \lambda_\mu \end{bmatrix}d\mu$$
$$+\begin{bmatrix} 0 \\ \lambda_\omega \end{bmatrix}d\omega + \begin{bmatrix} 0 \\ \lambda_{P_A} \end{bmatrix}dP_A + \begin{bmatrix} 0 \\ \lambda_\delta \end{bmatrix}d\delta + \begin{bmatrix} 0 \\ \lambda_F \end{bmatrix}dF$$

Again, we specify the utility function as $U = k_A C_A^{\alpha} + k_G C_G^{\beta}$, where $k_i > 0 \;\; i = A, G, \;\; 0 < \alpha \leq 1$ and $0 < \beta \leq 1$. The sign of $\lambda_{E_h} = \beta(\beta - 1)k_G \left[(1-\delta E_h)(C_G^e)^{\beta-2} + \delta E_h (C_G^c)^{\beta-2} \right] \left[f'(E_h)X \right]^2$

$+ \beta k_G \left[(1-\delta E_h)(C_G^e)^{\beta-1} + \delta E_h (C_G^c)^{\beta-1} \right] f''(E_h)X + 2\delta\alpha k_A \left[(C_A^e)^{\alpha-1} - (C_A^c)^{\alpha-1} \right] \omega / P_A$

$- 2\delta\beta k_G \left[(C_G^e)^{\beta-1} - (C_G^c)^{\beta-1} \right] f'(E_h)X$ is negative from the second order maximum condition. The sign of $\lambda_X = f'(E_h)\beta^2 k_G \left[(1-\delta E_h)(C_G^e)^{\beta-1} + \delta E_h (C_G^c)^{\beta-1} \right]$

$+ \alpha\mu S'(X)(C_A^e)^{\alpha-2} k_A \left[(1-\delta E_h)(1-\alpha)\omega / P_A - \delta C_A^e \right]$

$+ \delta\alpha\mu S'(X)(C_A^c)^{\alpha-2} k_A \left[\delta E_h (1-\alpha)\omega / P_A - \delta C_A^c \right]$

$- \delta\beta k_G \left[f(E_h)((C_G^e)^{\beta-1} - (C_G^c)^{\beta-1}) + m(C_G^e)^{\beta-1} \right]$ is assumed positive, which holds whenever μ and m are 'not too high'. Then, the determinant of the system, $\lambda_{E_h} - \lambda_X f'(E_h)K / r$, is negative.

The sign of $\lambda_m = (1-\delta E_h)\beta(1-\beta)k_G (C_G^e)^{\beta-2} f'(E_h)X^2 + \delta\beta k_G (C_G^e)^{\beta-1} X$ is positive, while the sign of $\lambda_\mu = \alpha k_A (C_A^e)^{\alpha-2} \left[(1-\delta E_h)(\alpha - 1)\omega / P_A + \delta C_A^e \right] S(X) / P_A$ is in general unclear. The signs of $\lambda_\omega = \alpha(\alpha-1)k_A \left[(1-\delta E_h)(C_A^e)^{\alpha-2} + \delta E_h (C_A^c)^{\alpha-2} \right] N\omega / P_A^2$

$+ \delta\alpha k_A \left[(C_A^e)^{\alpha-1} - (C_A^c)^{\alpha-1} \right] N / P_A \; + \alpha k_A \left[(1-\delta E_h)(C_A^e)^{\alpha} + \delta E_h (C_A^c)^{\alpha} \right] / P_A$ and

$\lambda_{P_A} = \alpha(\alpha-1)k_A \left[(1-\delta E_h)(C_A^e)^{\alpha-2}(A(E_A) - C_A^e) + \delta E_h (C_A^c)^{\alpha-2}(A(E_A) - C_A^c) \right] \omega / P_A^2$

$- \alpha k_A \left[(1-\delta E_h)(C_A^e)^{\alpha-1} + \delta E_h (C_A^c)^{\alpha-1} \right] \omega / P_A^2$

$+ \delta\alpha k_A \left[(C_A^e)^{\alpha-1}(A(E_A) - C_A^e) - (C_A^c)^{\alpha-1}(A(E_A) - C_A^c) \right] / P_A$ are unclear. The sign of

$\lambda_\delta = k_G \left[(C_G^e)^{\beta} - (C_G^c)^{\beta} \right] + k_A \left[(C_A^e)^{\alpha} - (C_A^c)^{\alpha} \right] - E_h \alpha k_A \left[(C_A^e)^{\alpha-1} - (C_A^c)^{\alpha-1} \right] \omega / P_A$

$+ E_h k_G \beta f'(E_h)X \left[(C_G^e)^{\beta-1} - (C_G^c)^{\beta-1} \right]$ is in general unclear. However, the first three positive terms dominates the fourth negative term if F, μ, and ω are 'high'. Finally,

$\lambda_F = \delta\alpha k_A (C_A^c)^{\alpha-2} \left[(1-\alpha)\omega E_h / P_A + C_A^c \right] / P_A$ is positive.

The welfare effect

Again, in order to investigate the impact on local welfare of a change in the exogenous parameters we must take into account the effect working through a changing wildlife stock (see section 1 in the appendix). The total differential of *(5)* gives the welfare effects in *(A4)*.

$$(A4)\quad dEW = \{\alpha k_A[(1-\delta E_h)(C_A^e)^{\alpha-1} + \delta E_h(C_A^c)^{\alpha-1}]\mu S'(X)/P_A$$

$$+\beta k_G[(1-\delta E_h)(C_G^e)^{\beta-1}(f(E_h)+m)+\delta E_h(C_G^c)^{\beta-1}f(E_h)]\}dX$$

$$+(1-\delta E_h)\beta k_G \beta k_G (C_G^e)^{\beta-1}Xdm \; +((1-\delta E_h)\alpha k_A(C_A^e)^{\alpha-1}S(X)/P_A)d\mu$$

$$+\alpha k_A[(1-\delta E_h)(C_A^e)^{\alpha-1}+\delta E_h(C_A^c)^{\alpha-1}](N/P_A)d\omega$$

$$+(\alpha k_A/P_A)\{(1-\delta E_h)(C_A^e)^{\alpha-1}[A(E_A)-C_A^e]+\delta E_h(C_A^c)^{\alpha-1}[A(E_A)-C_A^c]\}dP_A$$

$$-E_h\{k_A[(C_A^e)^{\alpha}-(C_A^c)^{\alpha}]+k_G[(C_G^e)^{\beta}-(C_G^c)^{\beta}]\}d\delta$$

$$-(\delta E_h \alpha k_A(C_A^c)^{\alpha-1}/P_A)dF$$

Here,

$dEW/dm = (1-\delta E_h)\beta k_G \beta k_G (C_G^e)^{\beta-1}X \; + \{\alpha k_A[(1-\delta E_h)(C_A^e)^{\alpha-1}+\delta E_h(C_A^c)^{\alpha-1}]\mu S'(X)/P_A$ $+\beta k_G C_G{}^{\beta-1}(f(E_h)+m)\}dX/dm$, where *dX/dm* is given from equation *(A3)*. The same procedure is used in order to derive the welfare effect of the remaining exogenous variables.

Appendix 2

The numerical analysis

As mentioned in the main text, the ecological model is specified for the numerical analysis at the scale of one km^2 and one year. The same scale is also used for the agricultural benefit, as well as the hunting benefit, given in 1998/99 prices. The protected area, consisting of Serengeti National Park (SNP) and its surrounding game reserves, covers an area of some 26 000 km^2 (TANAPA 1996). The 'outer area' is thought of as the surrounding area on the western edge of the protected land. Campbell and Hofer (1995) identify the catchement area, i.e. the region in which the poachers reside, as the area within a maximum distance of 45 km to the protected land. This region constitutes some 30 500 km^2 and is, in this numerical analysis, interpreted as the 'outer area'. The human population in this region is estimated to be about 1.1 million with an average household size of about 7 persons (Campbell and Hofer 1995). Accordingly, there will be about 5 households per km^2 in the outer area. On average, it is assumed that 2 persons per household work in agricultural production, hunting, and formal sector. Hence, the effort constraint *T* is 10 man-labour years and, hence, $10 = E_A + E_h + N$.

The numerical analysis is exemplified by the wildebeest exploitation. The wildebeest population is estimated to be about 1.3 million animals and the annual offtake to some 120 000 animals (Campbell and Hofer 1995). The wildlife density in the protected area is therefore 50 animals per km^2, while the offtake is some 5 animals per km^2. Following Campbell and Hofer (1995), it is assumed to be 0.2 hunters per average household in western Serengeti. Consequently, it is one person involved in hunting at full time basis for every 5 households, and the baseline value of E_h is accordingly 1. The hunting function in *(2)* is specified as $h = qE_h^{\gamma} X$, where *q* is the catchability coefficient and γ is a scale parameter. γ is set to 0.9 (Barrett and Arcese 1998). By imposing the baseline value of E_h into the hunting function with $h / X = 5 / 50$, *q* is calculated to 0.1. The baseline value of the legal offtake is calculated from the hunting quotas of SRCP for the year 2000 hunting season. Based on a quota of 15 wildebeest per project village, *m* is set to 0.0002. The maximum specific growth rate is fixed as *r* = 0.3 (Caughley and Sinclar 1994). To calculate the wildlife stock at its base level the carrying capacity *K* is set to 75 animals per km^2, meaning that the protected area can carry a stock of wildebeest just below 2 million animals.

The agricultural yield function is specified as $A(E_A) = z(E_A)^{\sigma}$ with z as a productivity parameter and σ as a scale parameter. The scale parameter is given as 0.8 (Barrett and Arcese 1998). According to a questionnaire among 300 households in Serengeti and Bunda Districts in 2001, the average plot size per household is 7.4 acres, corresponding to a cultivated area of a fraction of 0.15 per km^2 for the average 5 households (Johannesen 2002). For the same districts, the value of the crop production is estimated to US$ 5 861 000 or some US$ 19 000 per km^2 cultivated land (Emerton and Mfunda 1999). At our scale of one km^2, this represents a value of US$ 19 000×0.15 = US$ 2 850 (or US$ 570 per household). This is assumed to be representative for the whole outer area. The main crops grown in western Serengeti are sorghum, cassava, maize, and cotton (SRCP 1998). Personal communication with SRCP (1999) indicates a per kg price of US$ 0.18 for sorghum, US$ 0.05 for cassava, US$ 0.11 for maize, and US$ 0.19 for cotton. By weighting the crop prices by the relative magnitude of these crops (SRCP 1998), the price per kilo agricultural output equals US$ 0.15, so that P_A = 0.15. The time constraint in *(3)* gives $E_A = T - E_h - N = 10 - 1 - N$. Because a large fraction of the households in western Serengeti lack the opportunity of formal employment, it is assumed that only 20 per cent of the households have one person employed at full time basis in the formal sector. This means that the baseline value of *N* is set to 1 and, hence, E_A to 8. Consequently, the value of the crop production, i.e. $P_A z {E_A}^{0.8} = 2850$, is balanced with $z = 3600$. This means that one labour year in agricultural production gives an output of 3600 kilo crops.

The wage rate in formal employment follows from the first order condition in *(10)* which balances with $\omega = 285$, i.e. the annual income of full-time employment is US$ 285. This corresponds well with the average wage of US$ 0.8 per day paid in the food processing industry in Mara Region (Hofer et al. 2000). The income from tourism *S(X)* is interpreted as the revenue from public fees (entering fees, bed fees etc.) paid by tourists visiting SNP. According to Kauzeni and Kiwasila (1994), the income from fees in 1993 was US$ 420 000 or some US$ 5 per tourist. It is assumed that the average fee is fixed at the level of US$ 5. Kauzeni and Kiwasila (1994) report that the number of tourists visiting SNP in 1990 was 63 000 with an average annual growth equal to 7000 tourists in the period of 1984-1990. Using the same annual growth, the number of visitor in 1999 is calculated to 126 000. This gives an income from fees of US$ 630 000. Records from the village administration in Robanda show that this village received US$ 17 000 from the wildlife lodge in its village area. This corresponds to 3% of the annual tourism income and, hence, μ is set to 0.03. Because the model is specified at the scale of one km^2, we must correct for this in *S(X)*. The ratio of the tourism income to the value of crop production equals 0.11 which must also be the case at the scale of one km^2. Therefore, the baseline value of *S(X)* is set to 314. *S(X)* is specified as $P_T \varepsilon \ln X$, where $P_T = 5$ is the average fee paid per tourist and $\varepsilon \ln X$ is the number of tourists which depends on the wildlife density, where $\varepsilon > 0$. Then, solving for ε gives $\varepsilon = 16$.

When it comes to the probability of being caught in illegal hunting, Hofer et al. (2000) provide an estimate equal to 0.002 per day. If the hunter spends all hunting effort on one continuously hunting trip, then the probability of being caught equals $0.002 \times 365 = 0.7$. In reality, however, the hunter divides the hunting effort between several hunting trips so that the hunting effort also includes time spent travelling between the home area and the protected area. If the probability of being caught is lower when travelling outside the protected area, then a value of 0.7 represents an overestimation of δ. In the following, we set the baseline of δ to half of this value, i.e. $\delta = 0.35$. This means that the probability of being caught for a full time hunter is 0.35 a year. Based on Hofer et al. (2000), the fine *F* equals US$ 110.26. Finally, $U(C_A)$ is specified as $U = k_A C_A{}^{\alpha}$ with $\alpha = 0.5$ and $k_A = 1$, while $V(C_G)$ is specified as $V = k_G C_G{}^{\beta}$ with $\beta = 0.2$. Then, in order to fit the model to its baseline values k_G is set to 30. Table A1 summarises the baseline parameter values.

Table A1 about here

Table A2 about here

Tables

Table 1: The conservation effect of the respective policies and the corresponding welfare effect*.

	X^I	EW^I	X^{II}	EW^{II}
m	-	+ if μ, m are 'small'; - if μ, m are 'high'	+/-	+/-
μ	-	+ if $S'(X)$, m are 'small'; - if $S'(X)$, m are	+ if δ is 'high'; - if δ is 'low';	+** - if $S'(X)$, m are
ω	+ if N is 'low'; - if N is 'high'	+** +/- otherwise	+ if N is 'low'; - if N is 'high'	+** +/- otherwise
P_A	÷ if F, δ are 'high'; +/- otherwise	+/-	- if F, δ are 'high'; +/- otherwise	+/-
δ	+	+ if μ, m are 'high'; - otherwise	+ if F, μ, and ω are 'high' +/- otherwise	+ if μ is 'high' - otherwise
F	+	+ if μ, m are 'high'; - otherwise	+	+ if μ, m are 'high'; - otherwise

* This table reports possible negative impact of m, μ and ω on the welfare of the local people. This occurs because of the effect working through a changing wildlife stock. If we assume that the local people are not able to calculate the impact on the future stock size, they may accept higher transfers and a higher wage level even if the welfare effect turns out as negative.

** Here, given a positive conservation effect, the welfare effect is unambiguously positive.

Table 2: Simulation results of a changing culling fraction m*.

	No risk of exclusion		Risk of exclusion from meat distribution		Risk of exclusion from meat and money transfers	
	X^I	EW^I	X^{II}	EW^{II}	X^{II}	EW^{II}
$m = 0.0002$	50	185	50	185	50	185
$m = 0.09$	45	191	52	192	52	192
$m = 0.1$	44	192	50	193	50	193

* Here, X measures the stock density. All parameters except m are fixed at their respective baseline value.

Table 3: Simulation results of a changing wage rate ω*.

	X^I	EW^I
$\omega = 285$	50	185
$\omega = 430$	56	205
$\omega = 570$	58	228

* Here, X measures the stock density. All parameters except ω are fixed at their respective baseline value.

Table 4: Simulation results of a changing fine level F*.

	X^I	EW^I
$F = 110$	50	185
$F = 220$	53	185
$F = 440$	57	184

* Here, X measures the stock density. All parameters except F are fixed at their respective baseline value.

Table A1: Baseline values economical and ecological parameters

Parameter	Description	Value
P_A	Crop price	0.15 ($/kg)
α	Scale parameter utility of agric. output	0.5
k_A	Linear parameter utility of agric. output	1
β	Scale parameter utility of game meat	0.2

k_G	Linear parameter utility of game meat	30
σ	Input elasticity labour crop production	0.8
z	Productivity crop production	3600 (kg)
T	Available labour effort, man-labour years	10
q	Catchability coefficient	0.1
γ	Input elasticity labour hunting	0.9
ω	Wage rate formal employment	285 ($)
μ	Fraction of tourism income transferred to every 5 households	0.03
P_T	Average fee	5 ($/tourist)
ε	Constant, tourism income	16
δ	Marginal probability of detection	0.35
F	Fine imposed if detected in illegal hunting	110.26 ($)
m	Cropping ratio	0.0002
K	Carrying capacity	75 (animal/km^2)
r	Intrinsic growth rate	0.3

Table A2: Simulation results of changing the money transfers μ*.
In Regime II: link on money transfers only.

	X^I	EW^I	X^{II}	EW^{II}
μ = 0.03	50	185	50	185
μ = 0.15	50	186	51	186

* Here *X* measures the stock density. All parameters except μ are fixed at their respective baseline value.

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Notes

[1] When it comes to game meat distribution, the opposite result occurs in Skonhoft's model (1998). This stems from the fact that Skonhoft considers the local people as passive, while the park manager, who benefits from both legal hunting and tourism, is the active agent. When the state instructs the park manager to distribute a fraction of the legal harvest to the local people, the marginal return on hunting is reduced relative to the marginal return on non-consumptive tourism services and, consequently, the manager increases the investment in wildlife. With a passive local community, this promotes wildlife conservation.

[2] The intuition is that when a labour market is present the household is able to alter the effort use in agriculture by adjusting its labour supply in formal employment, while the effort use in wildlife harvesting is left unchanged, and vice versa.

[3] For a broad discussion of protected areas and law enforcement, see Martin (1993).

[4] See e.g. Wright (1999) for a further discussion of culling operations as a tool in wildlife management.

[5] There are assumed to be conflicting interests among the local people. Hence, prevalence of individual conformity to group norms is assumed to be present. In line with traditional reasoning, it is assumed that the elders are in charge of the group's activities (Marks 1984).

[6] Concavity of f may be due to technological restrictions such as access to weapons, transport etc. It is seen that if $f'' = 0$, *(2)* is in line with the Schaefer harvesting function.

[7] N is endogenous in this model. One may argue that there are constraints on the working hours in formal employment, which makes it difficult for individuals to adjust the working hours to changes in

the wage rate in that sector. However, T is interpreted as the size of the human population and, hence, changes in N are due to individuals choosing not to work or to enter employment in the formal sector without altering the individual working hours.

[8] We assume that the consumption level does not fall below a particular threshold or subsistence level at which point the local people would be attracted to the risk in order to avoid disaster.

[9] In the case of Serengeti the quota (mX) is set low relative to the wildlife stock for each village receiving meat from the culling program, meaning that m is low in the culling of today (see Appendix 2).

[10] For a discussion of a broader distribution scheme, see Brandon and Wells (1992).

[11] The absence of a market for game meat captures the nature of the village economy in this commodity in Serengeti (see also Barrett and Arcese 1998). While there is trade in meat among households within and between villages in the catchment area, there is a small and negligible trade outside the catchment area. See note 14-15 for the impact of a change in this assumption.

[12] Hence, the ecological equilibrium restricts the size of m: as X approaches zero $m = r - f(E_h)$.

[13] The actual welfare of the local people is strictly dependent on the realized consumption bundle, i.e. it is conditional upon whether they are caught in illegal hunting. More precisely, the actual welfare level is higher if the local people manage to escape the patrol units. However, we cannot observe which of the two states are realized. Instead, we investigate the welfare effect of ICDP by deriving its impact on the expected utility function.

[14] It can be demonstrated that the conservation effect is negative also when a market for game meat is present.

[15] If a market for game meat is present, then the money transfers work as lump sum transfers which do not alter the hunting decision of the local people. Hence, in this case, money transfers do not alter the size of the wildlife stock.

[16] Skonhoft and Solstad (1998) present a model of a producer (firm) who sells both agricultural output and game meat on the market, while no market exists for labour. In their model, the alternative cost of hunting equals the foregone return from agricultural production and, therefore, a higher agricultural price reduces the hunting effort. Assuming that a market exists for game meat, and $N = 0$ makes the present model similar to the profit-maximizing model of Skonhoft and Solstad (1998).

[17] The link presented here is implemented so that the management authority distributes money and meat at the end of a period, i.e. a quarter or a year. Then, the local people do not benefit if they have been caught in illegal hunting during that period.

[18] It is assumed that *(8)* reads $dX / dt = rX(1 - X / K) - f(E_h)X - mX$, also when the local people are caught in illegal hunting. This means that the park manager takes out a fraction *m* of the stock even if it is not distributed to the local people. Instead, the manager distributes the meat to the management staff or sells it on markets outside the region.

[19] Note that the conservation effect of an increased marginal probability of being caught (δ) is unclear in Regime II. The mechanism works as follows. First, a higher δ reduces the expected utility level, which works in the direction of reduced hunting effort. In addition, the expected marginal agricultural utility increases. This strengthens the first effect. However, a higher δ also increases the expected marginal utility of game meat consumption, which works in the direction of increased hunting effort.

If the first and second effects dominate, then the conservation effect of an increased marginal probability of being caught is positive. This will be the case if the fine level F, the money transfers from tourism μ, and the wage rate in formal sector ω are 'high'. It can be demonstrated that the conservation effect is positive for the numerical example presented in section 5.

[20] This revenue-sharing programme is of direct benefit to the village. In addition the district authorities and the State gain revenues from fees paid by the tourism sector (Kauzeni and Kiwasila 1994), but the villages complain that they do not gain any income from these fees. For a broad overview of tourism activities in Serengeti, see Kauzeni and Kiwasila (1994). For the objectives of Tanzanian National Parks regarding revenue sharing in tourism, see TANAPA (1996).