Conservation versus exploitation of wild animal species:

Property rights and conflicts

1. Introduction

Protected areas are widespread globally and are seen as the most important method of conserving wildlife and biodiversity. For African countries, the traditional objective has been to protect wild animals and natural habitats through strong restrictions on agricultural development and wildlife exploitation, the so called ‘fences and fines’ approach. This policy has, however, often worked against the social and economic interests of local people, and frequently transformed wildlife from a valuable commodity into a threat and nuisance (Kiss 1990, Swanson and Barbier 1992, Gibson and Marks 1995, Songorwa 1999). The ‘fences and fines approach’ has therefore been seen as one of several factors contributing to persistent illegal hunting pressure (e.g., Kiss 1990, Swanson and Barbier 1992), and hence the effectiveness of this type of conservation policy has been questioned.

Over the past decades, however, the scope of protected areas has broadened substantially to also include various measures to improve the the needs and living conditions of the local people (see, e.g., Locke and Dearden (2005) and Naughton-Treves et al. (2005) for reviews of the development of new protected areas categories). The most widespread strategy is integrated conservation and development projects (ICDPs), implemented with the dual goal to protect wildlife and biodiversity, but also enhance the economic development of people living close to protected areas (e.g., Kiss 1990; Wells and Brandon 1992). These projects involve varying levels of local participation, from pure benefit sharing (e.g., transfers from wildlife-based tourism) to a more far-reaching design of community-based management in which local communities are trained to manage and control park resources. Common to all schemes of local participation is the idea that benefits from wildlife as a renewable resource may trigger incentives to the local people to carefully manage wildlife as a valuable asset.[1]

This paper focuses on ICDPs based on pure benefit sharing strategies. More precisely, the focus is on ICDPs designed as revenue sharing schemes where a part of the park’s income is distributed to the local people as cash transfers. At first glance revenue transfers may seem likely to improve local welfare and reduce local people’s incentives to hunt wildlife. However, the actual impact may be limited by possible design dilemmas and trade-offs inherent in linking conservation and development. Existing bio-economic literature on parks and wildlife harvesting stress, e.g., that local people may incorporate new sources of income

[1] See Wells and Brandon (1992) for an overview of several ICDPs in developing countries.

as complements to existing activities (i.e., wildlife harvesting) rather than as substitutes for them. Consequently, revenue transfers may lead to increased wildlife harvesting and less conservation (Barrett and Arcese 1998; Johannesen 2006).

Another way of providing local people with park revenues is by compensating farmers for wildlife induced agricultural damages. However, damage compensation may typically work as an agricultural subsidy that stimulates agricultural expansion, which in turn may have negative impact on wildlife. Bulte and Horan (2007) present a bio-economic model of wildlife hunting and farming, and where both hunting and the size of natural habitat affect the wildlife stocks. They demonstrate that damage compensation stimulates habitat conversion and reallocates labor from wildlife hunting to agriculture. The first effect works in the direction of reducing the wildlife stock, whereas the second effect works in the opposite direction. Not surprisingly, they also show that compensation is less likely to work as intended when agricultural land is a poor substitute for natural habitat for wildlife.

Reviews of existing ICDPs have shown that benefit-sharing initiatives have been poorly linked to the conservation objective and hence, such initiatives rarely work (e.g., Wells et al. 1999). Ferraro (2001) and Ferraro and Kiss (2002), among others, stress the need to change incentives from indirect measures (say, through the agricultural sector) to direct measures; that is, transfers conditional on the conservation target. Zabel et al. (2011) analyze the impact of a conditional revenue transfer, where the transfer is made conditional on the size of the wildlife stock. Using a bio-economic model of wildlife harvesting and livestock herding, and where wildlife cause damage to livestock, they demonstrate that conditional transfers can encourage wildlife conservation. One underlying assumption of this model is that livestock herders have long-term interests in wildlife and thus take into account that their livestock activity affects the size of the future wildlife stock. However, this will for sure not always be the case, especially in situations where local people lack property rights to wildlife and see future access to wildlife as highly uncertain. Then local people may have short-term interests in wildlife, even though they receive a conditional transfer. In that case, the proposed transfer may typically increase the income of the local people without having any effect on wildlife harvesting.[2] In contrast, Johannesen (2006) considers the local people as having short term interests in wildlife and specifies the direct transfer as conditional on illegal hunting rather than the size of the wildlife stock. Then, revenue transfers are more likely to reduce illegal

[2] The same has been pointed out in case of ambient taxation in fisheries. See Jensen and Vestergaard (2002).

hunting and promote conservation if combined with policies that increase the probability of being caught in illegal hunting.

The purpose of this paper is to analyze the impact of park revenue transfers when these are made conditional on illegal hunting. Unlike Johannesen (2006), as well as the other models cited above, we expand the bio-economic model to include the interaction between the local people and the protected area manager. That is, while the above models focus on the local people only and hence, assume that they are the only agent harvesting wildlife, we incorporate the strategic interdependence between the two agents by assuming that they both harvest wildlife and respond to revenue transfers. We concentrate on revenue transfers from wildlife-based tourism in the park to the local people and, following Johannesen and Skonhoft (2005), we distinguish between transfers from safari hunting and transfers from non-consumptive tourism. However, in contrast to Johannesen and Skonhoft (2005), we specify these transfers as conditional on illegal hunting.

Just as Johannesen and Skonhoft (2005), we assume that the park manager has the legal property rights to wildlife and hence, long term interests in wildlife management. Furthermore, the park manager can invest in law enforcement in order to protect his property rights against illegal hunting by the local people. This contrasts the model in Fisher et al. (2011), where the local people instead invest in law enforcement.[3] The general set-up in Fisher et al. (2011) differs from ours as they assume that illegal hunting is performed by professional gangs from outside the local community.

Johannesen and Skonhoft (2005) consider the local people to have long term interests in wildlife due to the *de facto* property rights. In contrast, we assume that the local people have no legal property rights and furthermore, face a continuous risk of being effectively denied future access to wildlife due to law enforcement activities performed by the park manager. They have therefore short term interests in wildlife. The game in the present paper is therefore specified as a Stackelberg game with the park manager as the leader, whereas the property rights scheme as presented in Johannesen and Skonhoft (2005) implies a Nash game.

We start out by formulating a bio-economic model without transfers to the local people. This case is similar to that presented by Skonhoft and Solstad (1998) and describes how the game

[3] There is a debate concerning who should do the enforcing. Stevens (1997) and Wells and Brandon (1992) argue for involving local users in park monitoring and enforcement, whereas Bruner et al. (2001) argue that governments parks are most effective in enforcing rules.

between the park manager and the local people works. Then we expand the model to allow for transfers from the park manager to the local people. In the first case, transfers are made unconditional on illegal hunting. We then find that transfers from safari hunting promote wildlife conservation, whereas transfers from non-consumptive tourism results in less wildlife. Furthermore, the impact on illegal offtake and local welfare depends on type of transfer. In the second scenario we specify transfers as conditional on illegal hunting. Then transfers from safari hunting promote wildlife conservation, but less than in case of unconditional transfers. This result is surprising when seen in light of what is claimed elsewhere in the literature, namely that direct transfers will perform better. Transfers from non-consumptive tourism will again reduce the wildlife stock, but now less than in the unconditional case. Again, the impact on illegal offtake and local welfare depends on type of transfer implemented.

The paper is organized as follows. The basic structure of the model without transfers is presented in Section 2. Transfers made unconditional on illegal hunting are analyzed in Section 3. In Section 4, we model transfers as conditional on illegal offtake and analyze the performance of such direct transfers compared with unconditional transfers. Both scenarios are analyzed under biological and economic equilibrium. The analysis demonstrates some ambiguous effects regarding whether conditional transfers works better than unconditional, or not. To shed further light on this, section 5 presents a numerical analysis. Section 6 summarizes the main finding.

2. The pre-ICDP model

The biology

Let X represent the whole wildlife population. The wildlife population grows over time according to natural growth $F(X)$ and shrinks due to hunting. See equation (1). The park manager has the legal property rights to wildlife and hunt wildlife legally with an offtake of Y. However, the property rights of the park manager are not perfectly protected, and hence, the local people are not perfectly prevented from harvesting wildlife. H denotes the illegal offtake. As in Skonhoft and Solstad (1998), Johannesen and Skonhoft (2005), and Johannesen (2006) it is assumed that illegal hunting is performed by local people living in the vicinity of the protected area only. Poaching carried out by outsiders is therefore ignored. But see Fisher et al. (2011).

(1) $dX/dt = F(X) - Y - H$

The natural growth function is considered as a logistic function with $F(0) = F(K) = 0$ and $F(X) > 0$ in the domain $(0, K)$, where K is the carrying capacity, so that $F_{XX} < 0$. See also Figure 2.

Local people

Consider a local community who earn income from hunting wildlife and growing crops. Available time T is spent hunting T_H and cropping agricultural land T_A:

(2) $T = T_H + T_A$

The agricultural crop production function is defined by $A(T_A)$, which is increasing in agricultural effort at a decreasing rate, $A_{T_A} > 0$ and $A_{T_A T_A} \leq 0$. Land use, as well as the use of other inputs like fertilizer and pesticide, is assumed fixed. That is, we disregard threats to wildlife due to habitat conversion to agriculture. But see, e.g., Bulte and Rondeau (2007). The wildlife stock, X, destroys a proportion of potential crop harvest. Crop damage is specified as bX with $b > 0$ and $0 \leq bX \leq 1$ so that the net agricultural output is:

(3) $G = A(T_A)(1 - bX)$

The hunting production function is defined as

(4) $H = H(T_H, X)$,

which increases with the hunting effort, but at a decreasing rate, $H_{T_H} > 0$ and $H_{T_H T_H} \leq 0$. Moreover, for a given effort a higher stock of wildlife means a higher offtake, $H_X > 0$, and the marginal productivity of effort increases with the size of the wildlife stock, $H_{T_H X} > 0$.

The probability of being detected when hunting illegally is assumed to be an increasing function of the time spent hunting illegally and the level of law enforcement L and given by

(5) $\theta = \theta(T_H, L)$,

with $\theta_{T_H} > 0$ and $\theta_L > 0$. In addition, it is assumed that the marginal productivity of law enforcement is non-decreasing in the hunting effort, $\theta_{LT_H} \geq 0$.

If caught in illegal hunting, the local people are imposed a fixed fine F. When P^A and P^H denote the unit price of agricultural crops and wildlife offtake, respectively, the expected net income of the local people is given as:

(6) $E(\pi^L) = P^A A(T_A)(1 - bX) + P^H H(T_H, X) - \theta(T_H, L)F$

Here, E is the expectation operator and subscript 'L' denotes the case of the local people. Before solving the decision problem of the local people, a note on how they adapt to the ecology is necessary. As mentioned in section 1, the local people are granted no property rights to wildlife. It is therefore assumed that the decision problem of the local people is based on short-term interests. Technically, it is assumed that the local people allocate effort between hunting and agriculture in order to maximize present expected net income subject to the time constraint in (2), when treating the size of the wildlife population X as exogenous. This corresponds well with previous contributions such as Skonhoft and Solstad (1998), Bulte and Rondeau (2006), and Fisher et al. (2011), but differs from Johannesen and Skonhoft (2005). The latter consider the local people, as well as the park manager, as having long-term interest in wildlife stating that they have *de facto* property rights to wildlife because law enforcement is completely absent.

When assuming risk neutrality, the decision problem of the local people is to allocate effort between hunting and agriculture in order to maximize present expected net income (6) subject to the time constraint (2)[4]. The first order condition yields

(7) $P^A A_{T_A}(T_A)(1 - bX) \geq P^H H_{T_H}(T_H, X) - \theta_{T_H}(T_H, L)F,$

where function subscripts denote the first derivatives with respect to the respective variables. Solving (7) for T_H yields $T_H = T_H(X, L, P^A, P^H, b, T)$, which is zero if (7) holds as an inequality and positive otherwise. Obviously, $T_H(0, L, P^A, P^H, b, T, F) = 0$, that is, hunting effort is zero without wildlife. Furthermore, there may be some positive stock levels that are too low to make illegal hunting profitable.

When inserting this expression into (4), the optimal offtake by the local people for $T_H > 0$ is given by

[4] As wildlife is a nuisance, hunting also represents damage control. In reality, damage control is also preformed through fencing and other measures more directly related to protecting agricultural crops. Such measures are, however, neglected in the present model. See, however, Bulte and Rondeau (2007), who distinguish between effort used in hunting (i.e., for game meat) and defending agricultural fields against wildlife.

(8) $H = h(T_H(X, L; P^A, P^H, b, T, F), X) = H(X, L; P^A, P^H, b, T, F)$.

Figure 1 illustrates the illegal harvesting function, where there is no harvesting up to a certain stock level X_0. Increased anti-poaching law enforcement increases the probability of being caught in illegal hunting and hence, the hunting effort reduces and the illegal harvesting function shifts outwards. See figure 1. See Appendix 1 for more details.

Figure 1 about here

Park manager

The park manager obtains income from wildlife-based tourism by selling hunting licenses and non-consumptive tourism services. $P^Y Y$ is net income from selling hunting licenses, where Y is the legal offtake and P^Y is the fixed market price for hunting licenses. $W(X)$ represents net income from non-consumptive tourism, where more wildlife make the park more attractive to tourist but at a decreasing rate, i.e., $W_X(X) > 0$ and $W_{XX}(X) \leq 0$. The park manager holds the legal property rights to wildlife and has legal rights protect them by preventing local people from harvesting wildlife through anti-poaching law enforcement. zL is the law enforcement cost, where z is the fixed price per unit effort L. Equation (9) represents the current profit of the park manager. Subscript ‘P’ denotes the park manager case.

(9) $\pi^P = P^Y Y + W(X) - zL$

In absence of resource policies, there are externalities working. First, the traditional reciprocal harvesting externalities are present through the hunting benefits. Second, there are reciprocal stock externalities related to the stock values: more hunting by the park manager, *ceteris paribus*, induces a positive externality on the local people through a reduction in crop damage, whereas more hunting by the local people induces a negative external effect on the park manager through a reduced income from non-consumptive tourism.

The pre-ICDP solution

In contrast to the local people, the harvesting activity of the park manager is steered by long-term considerations due to the property rights system in place. In the first step, the park manager determines the legal offtake and law enforcement level so as to maximize present value profit, when taking into account the best response of the local people in (8). In the next step, the illegal offtake follows from the optimal choice of Y and L. This is a Stackelberg game where the park manager is the leader and the local people is the follower. Specifying the game as of Stackelberg-type corresponds to Skonhoft and Solstad (1998) and is somewhat similar to Fisher et al. (2011)[5].

Technically, the park manager maximizes (10) subject to the population dynamics in (1) and the best response of the local people in (8).

(10) $PV = \int_0^\infty [P^Y Y + W(X) - zL] e^{-\delta t} dt$

δ is the park manager's discount rate. The current value Hamiltonian of the problem is $\mathcal{H} = P^Y Y + W(X) - zL + \mu[F(X) - Y - H(X, L; P^Y, P^H, b, T, F)]$ with Y and L as the control variables, X as the state variable, and μ as the shadow price of wildlife. When an interior solution is assumed present, the first order conditions read $\partial\mathcal{H}/\partial Y = 0$, $\partial\mathcal{H}/\partial L = 0$, and $\partial\mu/\partial t = \delta\mu - \partial\mathcal{H}/\partial X$. This yields $P^Y - \mu = 0$, $-z - \mu H_L = 0$, and $\partial\mu/\partial t = \delta\mu - W_X - \mu F_X + \mu H_X$, respectively. Equations (11) and (12) give the reduced-form steady-state equilibrium.

(11) $z = -P^Y H_L(X, L; P^A, P^H, b, T, F)$

(12) $F_X(X) + W_X(X)/P^Y = \delta + H_X(X, L; P^A, P^H, b, T, F)$

Equation (11) states that the park manager should invest in anti-poaching law enforcement until the marginal cost z equals the marginal benefit of anti-poaching effort $-P^Y H_L$, i.e., the marginal reduction in illegal offtake valued by the price of a legal hunting license. Equation (12) is the present version of the Clark-Munro rule. The left-hand side reflects the marginal benefit of increasing the wildlife stock, where $W_X(X)/P^Y$ is the marginal stock value from non-consumptive tourism relatively to the price per unit hunting license. The right-hand side equals the marginal cost of increasing the wildlife stock, where H_X is the marginal stock externality related to illegal offtake. The marginal stock externality stimulates the park manager to reduce the wildlife stock. On the other hand, the wildlife stock is higher with a higher marginal stock value of wildlife in non-consumptive tourism.

Generally, equations (11) and (12) determine simultaneously the steady-state wildlife stock and anti-poaching effort. The illegal offtake in steady-state then follows from (8). In the next stage, the steady state legal offtake follows from (1) with $F(X) = Y + H(X, L; P^A, P^H, b, T, F)$. In Figure 2 the solution is illustrated and denoted by subscript '*'.

[5] Fisher et al. (2011) assume that poaching is performed by professional hunters from outside the local community who behave as followers, whereas the local people perform anti-poaching law enforcement.

The optimal wildlife stock is below what corresponds to the maximum sustainable yield (X^{msy}) if the marginal stock externality is strong and the marginal benefit ratio of the park manager is low, so that H_X, together with δ, dominates W_X/P^Y. In what follows, this case is generally assumed to be present.

Figure 2 about here

Before introducing benefit-sharing between the park manager and the local people, it is of interest to investigate the effects on wildlife conservation and local welfare of changes in the tourism values attached to wildlife. The results are summarized in Table 1.If the marginal value of wildlife in non-consumptive tourism increases, say, due to increased demand for tourism services, the left hand side of (12) increases which works in the direction of more wildlife. If the marginal productivity of anti-poaching effort increases with the size of the wildlife stock, i.e. $H_{XL} < 0$ (see Appendix 1), then the optimal level of anti-poaching effort increases as well. See (11). This strengthens the direct stock effect. Consequently, a higher marginal stock value in non-consumptive tourism results in increased wildlife conservation. However, by differentiating (6) with respect to X and L, it can be demonstrated that the impact on local welfare is unclear. Increased anti-poaching law enforcement works in the direction of reduced illegal offtake and local welfare. The impact of more wildlife on local welfare is, however, ambiguous and depends on whether the marginal harvesting benefit of wildlife dominates the marginal nuisance. See Appendix 1. If the marginal nuisance dominates the marginal benefit (henceforth referred to as the 'nuisance' case), the local welfare effect is negative. In the 'benefit' case, however, local welfare improves if the marginal harvesting benefit is high enough to also dominate the effect of increased anti-poaching law enforcement on the illegal offtake.

A higher price on safari hunting licenses (P^Y) lowers the marginal stock value in non-consumptive tourism relatively to the marginal value of wildlife in safari hunting. This results in a smaller wildlife stock. See also (12). Furthermore, a higher P^Y rises the marginal benefit of anti-poaching effort and hence, stimulates the park manager to increase L. This dampens the negative effect on wildlife conservation. Again, the effect on local welfare is ambiguous, but somehow opposite of the effect above. In the 'benefit' case a smaller wildlife stock and increased law enforcement result in reduced local welfare. In the 'nuisance' case, however, local welfare increases if the benefit of reduced crop damages is high enough to also dominate the welfare effect of increased anti-poaching law enforcement.

Table 1 about here

Increased marginal return on wildlife in tourism may therefore have contrasting effects on wildlife conservation depending on the type of tourism activities experiencing improvement. Furthermore, the impact on local welfare is highly unclear. Conservation is enhanced if the marginal willingness to pay for non-consumptive tourism services increases relatively to that of safari hunting. This can improve local welfare only in the 'benefit' case, whereas the local people are worse off in the 'nuisance' case. The next step is to allow for sharing of tourism revenues between the park manager and the local people – i.e., the ICDP situation – and analyze how different sharing mechanisms affect wildlife conservation and local welfare.

3. ICDP: Unconditional payments

We now consider the ICDP situation where the local people are granted some of the park benefits, and hence, some property rights over the wildlife. In what follows, we assume that the park manager is required to transfer parts of the park profit to the local people, and we introduce first the case where these transfers are made unconditional on illegal hunting. The latter means that the local people receive the transfers regardless of whether they hunt illegally, or not. With $0 \leq \alpha \leq 1$ and $0 \leq \beta \leq 1$ as the (exogenous) fractions of the income from safari hunting and non-consumptive tourism transferred to the local people, respectively, the present value profit of the park manager reads

(13) $PV = \int_0^\infty [(1-\alpha)P^Y Y + (1-\beta)W(X) - zL]e^{-\delta t}dt.$

The expected net income of the local people changes to

(14) $E(\pi^L) = P^A A(E_A)(1-bX) + P^H H(E_H, X) - \theta(E_H, L)F + \alpha P^Y Y + \beta W(X)$

Just as in the previous section, we assume a Stackelberg game and treat the local people as having short term interests in wildlife in the sense that they consider the stock size as exogenous. Consequently, the first order maximum condition and the reduced-form illegal harvesting function are again given by (7) and (8), respectively. However, transfers affect the decisions problem of the park manager as the relative value of the tourism activities changes. The park manager maximizes (13) subject to the population dynamics in (1) and the best response of the local people in (8). The first order conditions are now given by:

(15) $z = -(1-\alpha)P^Y H_L(X, L; P^A, P^H, b, T, F)$

(16) $F_X(X) + (1-\beta)W_X(X)/[(1-\alpha)P^Y] = \delta + H_X(X, L; P^A, P^H, b, T, F)$.

Following Johannesen and Skonhoft (2005), we consider three different schemes of transfers: (i) uniform transfers from the two activities, in which case $0 < \alpha = \beta < 1$; (ii) only transfers from safari hunting, in which case $0 < \alpha < 1$ and $\beta = 0$; and (iii) only transfers from non-consumptive tourism, in which case $0 < \beta < 1$ and $\alpha = 0$. Table 1 summarizes the results.

In case (i), (16) coincides with (12), meaning that uniform transfers do not change the relative value of non-consumptive tourism and safari-hunting and consequently, have no direct impact on the wildlife stock. From (15), however, we see that the marginal return on anti-poaching effort shrinks which stimulates the park manager to reduce L. This, in turn, increases the marginal external cost imposed on the park manager due to illegal hunting in (16) and stimulates the park manager to invest less in wildlife. Hence, uniformed transfers have a negative effect on wildlife conservation. See Appendix 3. The impact of uniformed transfers on local welfare is, however, unclear. Local welfare increases in the 'nuisance' case, both directly and indirectly due to reduced anti-poaching effort and wildlife conservation, but the total welfare effect in the 'benefit' case is not clear. See Table 2.

The conservation effect of uniformed transfers contrasts Johannesen and Skonhoft (2005), who find that unified transfers are consistent with more wildlife conservation. The reason why their result differs from the present is that they ignore anti-poaching law enforcement and consider the local people as having long-term interests in wildlife. The first implies that uniform transfers do not affect the decision problem of the park manager, while the second implies that uniform transfers provide the local people with increased incentives to conserve wildlife. In the present, however, uniform transfers stimulate the park manager to invest less in anti-poaching law enforcement which results in less wildlife conservation.

In case (ii), the value of non-consumptive tourism increases relatively to the value of safari hunting. Consequently, the park manager will invest more in wildlife. See (16). Again, however, due to increased α, the marginal return on anti-poaching effort shrinks which stimulates the park manager to reduce L. Both more wildlife and reduced law enforcement allow for increased illegal offtake. Still, the local welfare effect is ambiguous. It is positive for sure in the 'benefit' case, and may be positive in the 'nuisance' case if transfers and the income increase in illegal hunting are large enough to offsets the increase in crop damages.

Finally, consider case (iii). Now the marginal value of wildlife in non-consumptive tourism reduces relatively to the marginal value in safari hunting. This stimulates the park manager to invest less in wildlife. Due to similar reasoning as above, this result differ from that of Johannesen and Skonhoft (2005) who find that transfers from non-consumptive tourism have an unclear effect on wildlife conservation. Here, a smaller wildlife stock, in turn, reduces the marginal return on anti-poaching law enforcement and hence, L reduces. The effect on local welfare effect is, again, ambiguous. It may be positive in the 'benefit' case if transfers and reduced crop damages more than offset loss of income from illegal hunting, but is positive for sure in the 'nuisance' case

Table 2 about here

To sum up, just as in Johannesen and Skonhoft (2005), we find that transfers from safari hunting is the most promising way of sharing tourism benefits when it comes to the impact on wildlife conservation. In the 'benefit' case it will result in improved welfare as well. In the 'nuisance' case, however, the prospect of reaching the dual goal of increased wildlife conservation and local welfare, when relying on unconditional payments, is rather low. Then benefit sharing must be based on transfers from safari hunting and the amount transferred must be large enough to offset the welfare loss caused by increased crop damages. In contrast, uniformed transfers or transfers from non-consumptive tourism only, cannot ensure the goal of integrating conservation and development.

We have seen that unconditional transfers relying on transfers from non-consumptive tourism have negative impact on the park manager's incentives to conserve wildlife. In this case the park manager is instructed to share (non-consumptive) tourism benefits irrespective of whether the local people hunt illegally, or not. This reduces the marginal return on non-consumptive tourism relatively to safari hunting and hence, the park manager invests less in wildlife. Therefore, we now proceed by investigating whether benefit transfers may work as intended if the park manager is allowed to make benefit-sharing conditional upon illegal hunting so that transfers are made only if the local people are not caught in illegal hunting. The motivation behind this strategy is twofold. First, making such a conditional transfer is one way of designing what is referred to as a direct, as opposed to indirect, payment in the literature (see e.g., Ferraro 2001). Hence, as discussed in Section 1, direct transfers may be therefore be more promising in changing local people's incentives to hunt illegally. Second, conditional transfers may also change the park manager's incentives to conserve wildlife, of which has not been of focus in previous literature.

4. ICDP: Conditional payments

We now proceed to the ICDP situation where the park manager is allowed to retain transfers if local people are caught in illegal hunting. That is, if anti-poaching patrols detect illegal hunting, then no transfers are made and the probability for this scenario is $\theta(T_H, L)$. However, transfers are made if the park manager fails to detect illegal hunting, and the probability for this scenario is $1-\theta(T_H, L)$. Then the expected current profit of the park manager reads $(1-\theta(T_H, L)[1-\alpha)P^Y Y + (1-\beta)W(X)] + \theta(T_H, L)[P^Y Y + W(X)] - zL$, and hence, when rearranging, the present value profit equals

(17) $E(PV) = \int_0^\infty \{[1-\alpha(1-\theta(T_H, L))]P^Y Y + \big[1-\beta\big(1-\theta(T_H, L)\big)\big]W(X) - zL\big\}e^{-\delta t}dt.$

The expected net income of the local people changes to

(18) $E(\pi^L) = P^A A(T_A)(1-bX) + P^H H(T_H, X) - \theta(T_H, L)F + (1-\theta(T_H, L))[\alpha P^Y Y + \beta W(X)]$

The first order maximum condition for the local people, when assuming an interior solution yields

(19) $P^A A_{T_A}(T_A)(1-bX) = P^H H_{T_H}(T_H, X) - \theta_{T_H}(T_H, L)F - \theta_{T_H}(T_H, L)[\alpha P^Y Y + \beta W(X)].$

As seen in (19), and in contrast to the previous section, benefit-sharing has now a direct impact on effort used in illegal hunting. Even though we still treat the local people as having short term interests in wildlife, the inherent risk of losing potential transfers increases the marginal cost of hunting illegally and, all else equal, stimulates the local people to reduce time spent in illegal hunting compared to the previous case with unconditional transfers. The reduced-form illegal harvesting function is given by

(20) $H = h(T_H(X, L; \alpha, \beta, P^A, P^H, b, T, F), X) = H(X, L; \alpha, \beta, P^A, P^H, b, T, F).$

The park manager maximizes (17) subject to the population dynamics in (1) and the best response of the local people in (20). The first order conditions are now given by:

(21) $z = -\left[1 - \alpha\left(1 - \theta(T_H, L)\right)\right] P^Y H_L(X, L; \alpha, \beta, P^A, P^H, b, T, F) + \theta_L(T_H, L)[\alpha P^Y Y + \beta W(X)]$,

and

(22) $F_X(X) + \frac{[1-\beta(1-\theta(T_H,L))]W_X(X)}{\{[1-\alpha(1-\theta(T_H,L))]P^Y\}} = \delta + H_X(X, L; \alpha, \beta, P^A, P^H, b, T, F)$.

We note that when the probability of being detected in illegal hunting is zero (e.g., if anti-poaching effort is too costly, i.e. z is too high, to ensure an interior solution), then (21) and (22) coincide with (15) and (16), respectively, and hence, the solution is identical to that of unconditional transfers. However, the solutions differ whenever anti-poaching law enforcement is not too costly. In the following, we analyze the impact of transfers of type (i)-(iii) when made conditional on illegal hunting, and compare the results with the previous case of unconditional transfers and the pre-ICDP case. For the following, notice that the signs of the cross derivatives in the reduced form illegal harvesting function with respect to the transfers parameters are given as $H_{L\alpha} = H_{L\beta} = 0$, $H_{X\alpha} < 0$, and $H_{X\beta} < 0$ (see Appendix 4).

Conditional uniform transfers

In contrast to unconditional transfers, we see that the impact of (i) conditional uniform transfers ($0 < \alpha = \beta < 1$) on the equilibrium wildlife stock is positive. The reason is that, in present, uniform transfers reduce the marginal stock externality related to illegal hunting (i.e., $H_{X\alpha} < 0$). See (22) and Appendix 4. Therefore, uniform transfers stimulate increased wildlife conservation when specified as conditional on illegal hunting and, hence, $X^{II} > X^0 > X^I$.

The impact on anti-poaching law enforcement may be positive or negative. See (21). First, investment in anti-poaching law enforcement works as reducing illegal hunting and hence, reduces loss to the park manager in the safari hunting offtake due to illegal hunting. Transfers from safari hunting work as lowering the (expected) net price of safari hunting licenses and, hence, reduce the value of lost offtake in safari hunting. This effect is reflected in the first term on the left hand side of (21) and works in the direction of reduced law enforcement. Second, investment in anti-poaching law enforcement increases the probability of detecting illegal hunting and is therefore a way for the park manager to avoid transfers. Hence, this stimulates the park manager to increase the level of law enforcement when faced with conditional transfers. This is reflected in the second term on the right hand side of (21). The total effect on anti-poaching law enforcement is therefore ambiguous. However, law enforcement increases if the marginal productivity of law enforcement in terms of detecting illegal hunting is high relatively to its productivity in terms of reduced illegal hunting (the number value of θ_L/H_L is high).

When compared to unconditional transfers, conditional transfers stimulate increased anti-poaching effort via both effects in (21). The negative effect is now smaller in magnitude because a positive probability of detecting illegal hunting reduces the (expected) net value of lost offtake in safari hunting compared to (15). The second term of (21) is new compared to (15) and reflects that the park manager can now avoid transfers by investing in law enforcement. Hence, both effects stimulate the park manager to increase the anti-poaching effort level compared to unconditional transfers, that is $L^{II} > L^{I}$.

The impact of conditional uniformed transfers on local welfare is, however, unclear. Transfers have a direct positive effect on local welfare, but changes in the wildlife stock and law enforcement may have some unintended negative impacts. However, in the 'benefit' case, welfare is improved if the benefit of transfers and more wildlife offsets the negative impact of any increases in law enforcement. In the 'nuisance', welfare is improved if transfers more than offset the negative impact of increased agricultural damage and any increases in law enforcement. Table 3(i) summarizes the results.

Table 3(i)-(iii) about here

Conditional transfers from safari hunting

Consider now case (ii) with $0 < \alpha < 1$ and $\beta = 0$. The direct effects on the wildlife stock work through increased marginal value of non-consumptive tourism relatively to the marginal value of safari hunting and reduced marginal stock externality related to illegal hunting. See the second term on the left and on the right hand side of (22), respectively. Hence, the two effects work in the direction of increased wildlife conservation.

Again, the impact on the optimal level of anti-poaching law enforcement is unclear. However, law enforcement increases if the marginal productivity of law enforcement in terms of detecting illegal hunting is high relatively to its productivity in terms of reduced illegal hunting (the number value of θ_L/H_L is high). The results are summarized in Table 3(ii).

The local welfare effect of conditional transfers from safari hunting is unclear. However, in the 'benefit' case, local welfare is improved if the benefit of increased transfers and more wildlife dominates the negative impact of any increases in law enforcement. In the 'nuisance' case, welfare is improved if transfers more than offset the negative impact of increased agricultural damage and any increase in law enforcement. Table 3(ii) summarizes the results.

When comparing conditional and unconditional transfers from safari hunting, conditional transfers work better in terms of wildlife conservation. The reason is that the latter reduces the marginal stock externality related to illegal hunting, which is new compared to unconditional transfers.

Conditional transfers from non-consumptive tourism

Finally, consider case (iii) with $0 < \beta < 1$ and $\alpha = 0$. This reduces the marginal value of non-consumptive tourism relatively to the marginal value of safari hunting, and this effect works in the direction of less wildlife. However, the marginal stock externality related to illegal hunting reduces as well, which works in the opposite direction. The total effect on wildlife conservation is therefore unclear. If the marginal stock value in non-consumptive tourism is high relatively to the marginal stock externality so that $(1-\theta)W_X/P^Y > H_X$ in (22), then conditional transfers from non-consumptive tourism results in reduced wildlife conservation. See Table 3(iii).

In contrast to conditional transfers of types (i)-(i), conditional transfers from non-consumptive tourism have an unambiguously positive effect on the optimal level of anti-poaching law enforcement is unclear.

The impact on local welfare is again unclear. Local welfare increases if the benefit of increased transfers more than offset any negative impact of increased law enforcement and a changing wildlife stock level.

When comparing conditional and unconditional transfers from non-consumptive tourism, conditional transfers work better in terms of wildlife conservation. Again, the reason is that conditional transfers reduce the marginal stock externality related to illegal hunting, which is new compared to unconditional transfers.

To sum up, when comparing the results of sections 3 and 4, we see that conditional transfers work leads to increased wildlife conservation when based on transfers from safari hunting only or uniformed transfers. Furthermore, transfers made conditional on illegal hunting perform better in terms of wildlife conservation than unconditional transfers. The reason is twofold: First, in case (i)-(ii), conditional transfers reduce the marginal stock externality by affecting local people's incentives to hunt directly, which stimulates the park manager to invest more in wildlife. Second, in case (ii), conditional transfers stimulate increased investment in wildlife by increasing the marginal valuation of non-consumptive tourism relatively to safari hunting compared to unconditional transfers. Even though conditional transfers perform better in terms of wildlife conservation, their impact on local welfare is unclear and strictly dependent on whether the direct positive effect of receiving transfers more than offset any negative impact of changes in the wildlife stock level and the level of anti-poaching law enforcement. To shed further light on this, the paper proceeds by presenting some numerical results in section 5.

5. Numerical example

To be written

6. Concluding remarks

To be written

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Appendix 1

The properties of $H = h(X, L; P^A, P^H, b, T, F)$ can be derived by first, taking the total differential of (7) (with equality) with respect to T_H, X, and L which yields

(i) $\left[P^A A_{T_A T_A}(1 - bX) + P^H H_{T_H T_H} - \theta_{T_H T_H} F\right] dT_H = -[P^A A_{T_A} b + P^H H_{X T_H}] dX + \theta_{L T_H} F dL$

where $P^A A_{T_A T_A}(1 - bX) + P^H H_{T_H T_H} - \theta_{T_H T_H} F < 0$ from the second order condition for maximum. Hence, if $\theta_{T_H T_H} < 0$ its magnitude must be restricted. $\partial T_H^* / \partial X$ is therefore positive, while $\partial T_H^* / \partial L$ is negative. Second, the derivatives of the reduced form illegal harvesting function then read

(ii) $H_X = h_{T_H} \partial T_H^* / \partial X + h_X > 0$

and

(iii) $H_L = h_{T_H} \partial T_H^* / \partial L < 0$.

Differentiating (iii) with respect to X then gives the cross effect

(iv) $H_{XL} = (h_{T_H T_H} \partial T_H^* / \partial X + h_{T_H X}) \partial T_H^* / \partial L + h_{T_H} \partial^2 T_H^* / (\partial L \partial X)$.

$h_{T_H T_H} \leq 0$, $h_{T_H X} > 0$, and $h_{T_H} > 0$, while the sign of $\partial^2 T_H^* / (\partial L \partial X)$ is unclear. The sign of (iv) is therefore in principle unknown. However, if $\partial^2 T_H^* / (\partial L \partial X) = 0$ and a Schaefer harvesting function is present so that $h_{T_H T_H} = 0$, we obtain $H_{XL} < 0$. On the other hand, if $\partial^2 T_H^* / (\partial L \partial X) = 0$, but $h_{T_H T_H} < 0$, the sign of H_{XL} is unclear. In discussing the comparative static results we assume that H_{XL} it is negative.

We obtain the second order derivative with respect to L as

(v) $H_{LL} = h_{T_H T_H} (\partial T_H^* / \partial L)^2 + h_{T_H} \partial^2 T_H^* / \partial L^2$.

The sign of H_{LL} is therefore also unclear. When assuming a Schaefer harvesting function, the sign of H_{LL} depends on the sign of $\partial^2 T_H^* / \partial L^2$. From the second order conditions in the optimization problem of the park manager (see Appendix 2), $H_{LL} \geq 0$ must hold.

Appendix 2

Differentiating (11) and (12) yields

(i) $$\begin{bmatrix} P^Y(F_{XX}-H_{XX})+W_{XX} & -P^Y H_{XL} \\ -P^Y H_{XL} & -P^Y H_{LL} \end{bmatrix}\begin{bmatrix} dX \\ dL \end{bmatrix} = \begin{bmatrix} H_X - F_X - \delta \\ H_L \end{bmatrix} dP^Y + \begin{bmatrix} -1 \\ 0 \end{bmatrix} d\omega,$$

where ω is a shift parameter for changes in the marginal valuation of wildlife in non-consumptive tourism. The determinant of the matrix on the left hand side is positive from the second order maximum condition. Furthermore, we must have $P^Y(F_{XX}-H_{XX})+W_{XX} \leq 0$. This implies that $H_{LL} > 0$ and that there must be a restriction on the magnitude of H_{XL}.

Differentiating (6) with respect to $X$and L gives the corresponding changes in the welfare of the local people:

(ii) $dE(\pi^L) = [-P^A A(T_A)b + P^H H_X]dX - FdL.$

The sign of $[-P^A A(T_A)b + P^H H_X]$ is positive in the 'benefit' case and negative in the 'nuisance' case. (i) and (ii), together with the differential of (8) and (1) (with $dX/dt = 0$), give the partial derivative effects shown in Table 1.

If the marginal productivity of anti-poaching effort increases with the size of the wildlife stock, i.e. $H_{XL} < 0$, then equations (11) and (12) simultaneously determine X^* and L^*. The impact of changing the marginal value of the tourism activities in section 2 will therefore be somewhat different. Increased marginal value of wildlife in non-consumptive tourism will increase the wildlife stock. Now, more wildlife stimulates increased use of law enforcement, which in turn, has a negative impact on the illegal offtake, as opposed to the case $H_{XL} < 0$. The total effect on the illegal offtake is therefore unclear. Furthermore, increased law enforcement adds a negative impact on local welfare which may cause a reduction in local welfare even in the 'benefit' case.

Allowing for $H_{XL} < 0$ will not alter the qualitative effects of increased price of safari hunting licenses.

Appendix 3

Differentiating (15) and (16) yields

(i) $$\begin{bmatrix} P^Y(F_{XX}-H_{XX})+(1-\beta)W_{XX}/(1-\alpha) & -P^Y H_{XL} \\ -(1-\alpha)P^Y H_{XL} & -(1-\alpha)P^Y H_{LL} \end{bmatrix}\begin{bmatrix} dX \\ dL \end{bmatrix} =$$

$$\begin{bmatrix} -(1-\beta)W_X/(1-\alpha)^2 \\ -P^Y H_L \end{bmatrix} d\alpha + \begin{bmatrix} W_X/(1-\alpha) \\ 0 \end{bmatrix} d\beta,$$

where, as in Appendix 2, the determinant on the left hand side D is positive, $P^Y(F_{XX} - H_{XX}) + W_{XX}$ is non-positive, H_{LL} is positive, and H_{XL} is negative but restricted in magnitude.

Differentiating (14) gives the corresponding changes in the welfare of the local people:

(ii) $dE(\pi^L) = [-P^A A(T_A)b + P^H H_X]dX - FdL + P^Y Y d\alpha + W d\beta.$

(i), together with (ii) and (1) (with $dX/dt = 0$), give the partial derivative effects shown in Table 2.

(15) and (16) determine X and L simultaneously. Hence, while changes in α and/or β affects X directly in (16), there is also an indirect effect working through a changing L from (15). When discussing the comparative static results in the main text, it is assumed that any indirect effect is dominated by the direct effect.

Appendix 4

Differentiating (21) and (22) yields

(i)

$$\begin{bmatrix} P^Y(F_{XX} - H_{XX}) + \frac{(1-\beta(1-\theta))}{(1-\alpha(1-\theta))} W_{XX} & -P^Y H_{XL} + \frac{\theta_L(\beta-\alpha)}{[1-\alpha(1-\theta)]^2} W_X \\ -\big(1-\alpha(1-\theta)\big)P^Y H_{XL} + \theta_L \beta W_X & -(1-\alpha)P^Y H_{LL} - \alpha\theta_L P^Y H_L - \theta_{T_H} P^Y H_L \frac{\partial T_H}{\partial L} \end{bmatrix} \begin{bmatrix} dX \\ dL \end{bmatrix} =$$

$$\begin{bmatrix} -\frac{\big(1-\beta(1-\theta)\big)}{[1-\alpha(1-\theta)]^2}(1-\theta)W_X + P^Y H_{X\alpha} \\ -(1-\theta)P^Y H_L - \theta_L P^Y Y - \alpha(1-\theta)P^Y H_{L\alpha} \end{bmatrix} d\alpha + \begin{bmatrix} \frac{(1-\theta)}{(1-\alpha(1-\theta))} W_X + P^Y H_{X\beta} \\ -\theta_L W - \alpha(1-\theta)P^Y H_{L\beta} \end{bmatrix} d\beta.$$

Again, the determinant on the left hand side is positive from the second order maximum condition. $P^Y(F_{XX} - H_{XX}) + W_{XX}$ is non-positive, H_{LL} is positive, and H_{XL} is negative but restricted in magnitude.

Differentiating (18) gives the corresponding changes in the welfare of the local people:

(ii) $dE(\pi^L) = [-P^A A(T_A)b + P^H H_X + (1-\theta)\beta W_X]dX - \theta_L[F + \alpha P^Y Y + \beta W]dL + (1-\theta)P^Y Y d\alpha + (1-\theta)W d\beta.$

Again, differentiating the reduced form harvesting function with respect to X and L gives

(iii) $H_X = h_{T_H}\partial T_H/\partial X + h_X > 0$

and

(iv) $H_L = h_{T_H}\partial T_H/\partial L < 0.$

Differentiating (iii) with respect to X then gives the cross effect

(v) $H_{XL} = (h_{T_H T_H}\partial T_H/\partial X + h_{T_{HX}})\partial T_H/\partial L + h_{T_H}\partial^2 T_H/(\partial L \partial X)$.

When assuming again that $\partial^2 T_H/(\partial L\partial X) = 0$ and that the Schaefer harvesting function applies, so that $h_{T_H T_H} = 0$, we obtain $H_{XL} < 0$.

Differentiating (ii) and (iii) with respect to α and β, respectively, when assuming that $\partial^2 T_H/\partial X\partial\alpha = \partial^2 T_H/(\partial X\partial\beta) = 0$ and that the Schaefer harvesting function applies, gives

(vi) $H_{X\alpha} = h_{T_H T_H}(\partial T_H/\partial X)(\partial T_H/\partial\alpha) + h_{T_{HX}}\partial T_H/\partial\alpha + h_{T_H}\partial^2 T_H/(\partial X\partial\alpha) = h_{T_{HX}}\partial T_H/\partial\alpha < 0$

(vii) $H_{X\beta} = h_{T_H T_H}(\partial T_H/\partial X)(\partial T_H/\partial\beta) + h_{T_{HX}}\partial T_H/\partial\beta + h_{T_H}\partial^2 T_H/(\partial X\partial\beta) = h_{T_{HX}}\partial T_H/\partial\beta < 0$

(viii) $H_{L\alpha} = h_{T_H T_H}(\partial T_H/\partial L)(\partial T_H/\partial\alpha) + h_{T_H}\partial^2 T_H/(\partial L\partial\alpha) = 0$

(ix) $H_{L\beta} = h_{T_H T_H}(\partial T_H/\partial L)(\partial T_H/\partial\beta) + h_{T_H}\partial^2 T_H/(\partial L\partial\beta) = 0$

(21) and (22) determine X and L simultaneously. Hence, while changes in α and/or β affects X directly in (22), there is also an indirect effect working through a changing L from (21). When discussing the comparative static results in the main text, it is assumed that any indirect effect is dominated by the direct effect.

Figures and tables

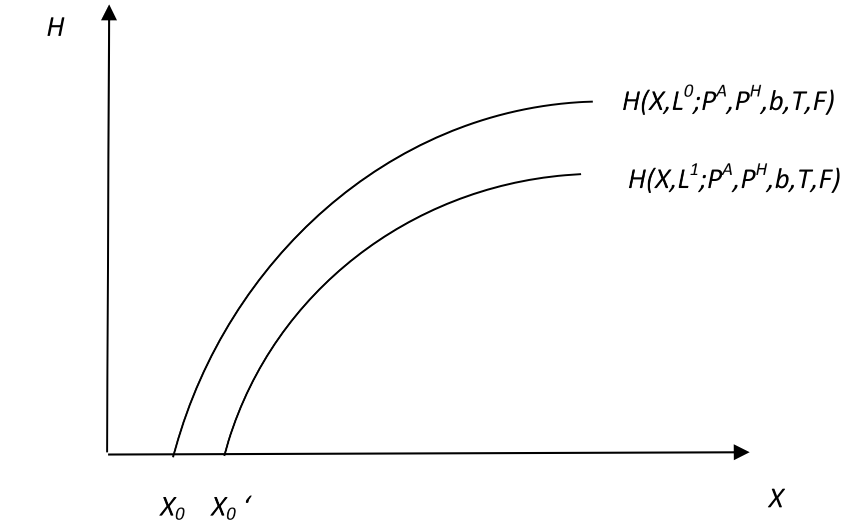

Figure 1: The illegal harvesting function. $L^0 < L^1$.

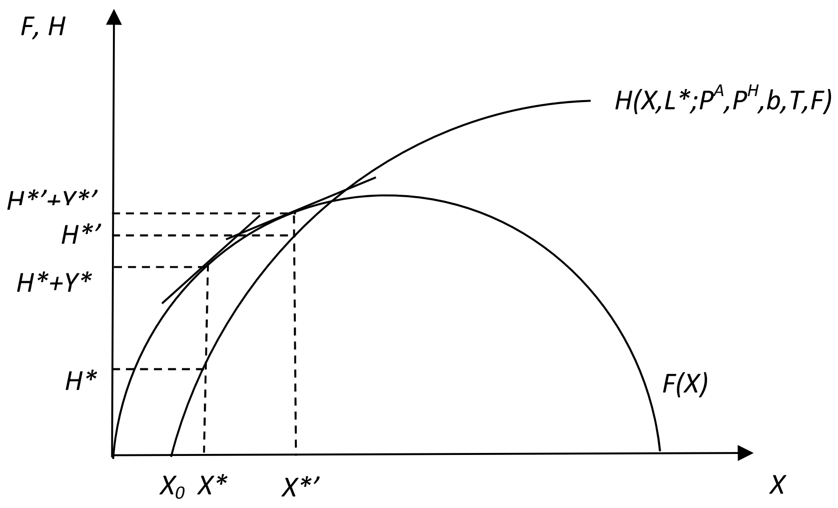

Figure 2: The steady-state solution, X^*, H^*, and Y^*. The slope of the tangent equals $\delta + H_X(X,L^*;P^A,P^H,b,T,F) - W_X(X)/P^Y$. Increased marginal stock value of wildlife in non-consumptive tourism reduces the slope of the tangent and results in a new steady-state solution, $X^{*\prime}, H^{*\prime}$, and $Y^{*\prime}$. $H_{XL} = 0$.

Table 1: Comparative statics.

	P^Y		ω	
X	-		+	
L	+		+	
H	-		+/-	
Y	+		+/-	
$H+Y$	-		+	
	‘benefit’:	‘nuisance’:	‘benefit’:	‘nuisance’:
$E(\pi^L)$	-	+/-	+/-	-

Note: The effects on the total harvest (*H* + *Y*) is calculated when the stock is below that of the maximum sustainable yield.

Table 2: Comparative statics. ICDP: Unconditional payments.

	(i) $\alpha = \beta$		(ii) $\alpha > 0, \beta = 0$		(iii) $\beta > 0, \alpha = 0$	
X	-		+		-	
L	-		-		-	
H	+/-		+		+/-	
Y	+/-		-		+/-	
$H+Y$	-		+		-	
	‘benefit’	‘nuisance’	‘nuisance’	‘nuisance’:	‘benefit’:	‘nuisance’:
$E(\pi^L)$	+/-	+	+	+/-	+/-	+

Note: The effects on the total harvest (*H* + *Y*) are calculated when the stock is below that of the maximum sustainable yield.

Table 3 (i): Comparative statics. ICDP: Conditional payments, uniform transfers, $\alpha = \beta$.

	θ_L/H_L high		θ_L/H_L low	
X	+		+	
L	+		-	
H	+/-		+	
Y	+/-		+/-	
$H+Y$	+		+	
	‘benefit’	‘nuisance’	‘benefit’	‘nuisance’
$E(\pi^L)$	+/-	+/-	+	+/-

Note: The effects on the total harvest (*H* + *Y*) are calculated when the stock is below that of the maximum sustainable yield.

Table 3 (ii): Comparative statics. ICDP: Conditional payments, transfers from safari hunting, $\alpha > 0, \beta = 0$.

	θ_L/H_L high		θ_L/H_L low	
X	+		+	
L	+		-	
H	+/-		+	
Y	+/-		+/-	
$H+Y$	+		+	
	'benefit'	'nuisance'	'benefit'	'nuisance'
$E(\pi^L)$	+/-	+/-	+	+/-

Note: The effects on the total harvest (*H* + *Y*) are calculated when the stock is below that of the maximum sustainable yield.

Table 3 (iii): Comparative statics. ICDP: Conditional payments, transfers from non-consumptive tourism, $\alpha = 0, \beta > 0$

	$(1-\theta)W_X/P^Y > H_X$		$(1-\theta)W_X/P^Y < H_X$	
X	-		+	
L	+		+	
H	-		+/-	
Y	+/-		+/-	
$H+Y$	-		+	
	'benefit'	'nuisance'	'benefit'	'nuisance'
$E(\pi^L)$	+/-	+	+/-	+/-

Note: The effects on the total harvest (*H* + *Y*) are calculated when the stock is below that of the maximum sustainable yield.