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Wanted dead and alive: to what extent are hunting and protection of an endangered species compatible?

ELIZABETH J. Z. ROBINSON
Environment for Development Tanzania, Department of Economics, University of Dar Es Salaam, and Research Associate, Centre for the Study of African Economies, University of Oxford. Email: ejzrobinson@hotmail.com

ABSTRACT. Cash-constrained wildlife departments must increasingly look towards revenue-generating activities such as sales of permits for hunting common species combined with fines for those caught with rare species. Pertinent to west Africa, an optimal enforcement model demonstrates the conditions under which a department with neither external budget nor tourism revenue can fully protect a rare species, and the impact on other species and local hunters' livelihoods. The department's effectiveness is shown to depend critically on the extent to which hunters can discriminate among different species. Improvements in hunting technology selectivity are therefore a substitute for increased enforcement spending.

1. Introduction

This paper considers the conditions under which it is possible for a wildlife department in west Africa without an external budget to protect fully a rare species from illegal hunting. Typically, the major expense for a wildlife department is enforcement and so the key theoretical contributions of the paper are to the optimal enforcement literature. However, the paper is of practical importance given that cost recovery is an increasing reality in sub-Saharan Africa, where wildlife and forest departments must function in an environment of insufficient or no government funding. In Tanzania, east Africa, the parastatal TANAPA (Tanzania National Parks Authority) receives no direct government funding but is able to obtain sufficient funds from tourism gate revenues supplemented by external donors. In contrast, in west Africa, the motivation for this paper, revenue from tourism is currently very limited, in part because there are few charismatic species to attract tourists or 'trophy' hunters in significant numbers. Further, the benefits from protecting wildlife, such as protection of biodiversity and existence values, do not naturally translate into income for the department. Hunting is typically for meat, undertaken illegally by villagers and professional hunters, thereby generating benefits for the community but no revenue for the wildlife department (Bowen-Jones *et al*., 2002, 2003).[1]

[1] Alternative funding mechanisms to protect wildlife and other resources are being developed, such as debt-for-nature swaps and payments for environmental

Becker (1968) posed the fundamental issues for law enforcement, asking how many offences should be permitted and how many offenders should go unpunished so as to maximize social welfare. Typically, in this optimal enforcement literature a game theoretic approach is adopted in which the enforcement agency acts as the Stackelberg leader, choosing the equilibrium level of enforcement that takes into account costs of enforcement and the strategic interaction between his decision and that of the individual (the follower) undertaking the illegal activity. Many such models are found in the literature (including Demsetz, 1964; Stigler, 1970; Sutinen and Andersen, 1985; Milliman, 1986, Shavell, 1993; Skonhoft and Solstad, 1996). However, for under-funded wildlife departments throughout sub-Saharan Africa the concept of maximizing social welfare is rarely of practical relevance. Other than the problem of accurately determining the social value of wildlife in a particular park or forest, the current reality is that insufficient funds are available to protect all endangered species, even if socially optimal. The key pragmatic policy question, addressed in this paper, is to what extent the department can generate sufficient revenue to protect the country's wildlife, particularly rare and endangered species.

This paper, in addressing cost recovery through hunting revenue, raises several theoretical and policy issues. First, when cost recovery is an objective, fines can no longer be considered as simply transfers from the hunter to the wildlife manager – as would be the typical assumption in the optimal enforcement literature. Rather, fines, possibly along with revenues from the sale of hunting permits, become key revenue sources, implying that the probability of detection is unlikely to be independent of the level of the fine.[2] Second, the sale of permits implies the legalization of some hunting. But it also implies that villagers who might have previously hunted 'for free' but at the risk of being caught, or freely within an open access environment, will be required to purchase the hunting permits that pay for the protection of the endangered species, suggesting, at least in the short run, reduced welfare for traditional hunters. Finally, the ability of the wildlife department to both recover its costs and protect rare species is shown to depend critically on the extent to which hunters themselves can discriminate among different species when hunting. Investments to improve the discriminatory powers of hunting technologies could have significant benefits, in terms of reducing the number of rare and endangered animals killed, and so could be considered a substitute for increased enforcement budgets.

services (see, for example, Le Quesne and McNally, 2005; Conservation Finance Alliance, 2006).

[2] Typically, revenue from fines is deposited in a government's general revenue fund. However, where control over enforcement has been decentralized, such as in Ghana where efforts are being undertaken to decentralize control over natural resources to the district or even community level, there is scope for fine revenue to remain within the local authority. There are similar examples in richer countries. For example, in Scotland, partnerships are being formed to manage road 'safety cameras'. These partnerships are funded on a cost recovery basis and are allowed to recover the costs of safety camera activity from fine revenue (Scottish Safety Camera Programme, n.d.).

2. Model

A regulatory agency is responsible for the wildlife in a forest. To keep the model analytically tractable, there are only two species, which are, from the hunters' perspective, to some extent valuable when sold as bushmeat, the price being driven by consumer preferences. From the regulatory agency's perspective, the species are either rare and socially valuable, or common, in which case they have no value over and above their value as bushmeat. The most interesting scenario, and the focus of this paper, is that in which the rare animal is also the more valuable as bushmeat and so valued highest by both the government (when the animal is alive) and the hunter (when the animal is dead). One of many such examples is the drill (*Mandrillus leucophaeus*) in Cameroon, which is both endangered and a preferred bushmeat species.[3]

The agency has no external budget, but it does have two strategies that can be used separately or in combination: the imposition of fines and the introduction of hunting permits. To avoid lengthy less interesting reformulations of the model, permits are sold only for hunting the common species, and fines are imposed on hunters caught with a rare animal or with a common animal without a permit.

A large number of risk-neutral potential hunters, N, identical in all respects except for their opportunity costs of labour, w_i, which vary uniformly between $w_{\min}$ and $w_{\max}$, live in and around the forest.[4] Each hunter is permitted a single hunting expedition, using a gun, from which he takes home only one animal.[5] A Poisson arrival models the opportunity a hunter gets to shoot an animal. More-palatable (and rare) animals, denoted by the subscript M, arrive at a rate λ_M and less-palatable (common) animals, denoted by the subscript L, arrive at a rate λ_L. The probability, α, that a more-palatable animal arrives first is $\lambda_M/(\lambda_M + \lambda_L)$. Similarly, the probability, $1-\alpha$, that a less-palatable arrives first is $\lambda_L/(\lambda_M + \lambda_L)$. The market price of the less-palatable common animal is chosen to be the numeraire; the market price of the more-palatable rare animal is y ($y > 1$). Hunters are accurate – if they shoot, they do not miss. Hunters who are able to discriminate can identify an animal that turns up and therefore choose whether or not to shoot. Non-discriminating hunters will always shoot an animal that turns up, but choose whether to take

[3] In cases where animals and birds are sold live, almost always the most privately valuable species will also be the most endangered species.

[4] The assumption of such heterogeneity among hunters is reasonable in a rural setting where land and labour markets do not function efficiently and where hunters are also farmers.

[5] The hunting period is considerably less than the reproductive cycle of either species. Further, the emphasis of the paper is on cost recovery and not detailed modelling of population dynamics and so the paper focuses on a single hunting expedition. The assumptions of the model in this paper enable analytical tractability whilst not compromising the key contribution of the model. They are also in keeping with empirical findings. For example, Tutu *et al.* (1993) found the average catch per hunt in Ghana to be 1.29 animals and the average length of a hunting trip 4.42 hours.

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home the animal that they have shot or discard it and wait for a different species.[6]

2.1. Zero enforcement

For comparison, hunting without enforcement is briefly analysed. The hunter's objective is to maximize his expected net revenues V from hunting. The hunter's choice is essentially the same whether or not he can discriminate before he shoots (in practice, bullets are costly). When an animal turns up the discriminating hunter chooses whether to shoot or wait for an animal of a different species. The non-discriminating hunter always shoots but then chooses whether to keep this animal, or to discard it and wait. A Poisson arrival process is assumed: if the hunter initially waits/discards he will continue to do so until a different species arrives. Using simple backwards induction the optimisation can therefore be considered as follows: once an animal of one species turns up the hunter must choose whether to keep that animal and get certain returns of 1 (if common), y (if rare), or to "gamble" and wait with expected returns $y - w_i/\lambda_M$ (if waiting for the rare species) or $1 - w_i/\lambda_L$ (common species). The hunter therefore chooses from the following discrete set: S_T, hunt and shoot and keep the first animal that turns up; S_M, hunt and shoot (if discriminating)/keep (if non-discriminating) only rare and more palatable species; S_L, hunt and shoot/keep only common and less palatable species, and; S_0, do not hunt.

$$\max E\{V\} = \max_{S_T, S_M, S_L, S_0} \{E\{V(S_T)\}, E\{V(S_M)\}, E\{V(S_L)\}, E\{V(S_0)\}\}$$

$$\begin{aligned} \text{where } E\{V(S_T)\} &= \alpha\left(y - \frac{w_i}{\lambda_M}\right) + (1-\alpha)\left(1 - \frac{w_i}{\lambda_L}\right) \\ E\{V(S_M)\} &= \alpha\left(y - \frac{w_i}{\lambda_M}\right) + (1-\alpha)\left(y - \frac{w_i}{\lambda_L} - \frac{w_i}{\lambda_M}\right) \\ E\{V(S_L)\} &= \alpha\left(1 - \frac{w_i}{\lambda_L} - \frac{w_i}{\lambda_M}\right) + (1-\alpha)\left(1 - \frac{w_i}{\lambda_L}\right) \\ E\{V(S_0)\} &= 0. \end{aligned} \tag{1}$$

The above equations can be interpreted in the following way: $\alpha(y - w_i/\lambda_M)$ is the probability of a rare animal turning up first, multiplied by the expected returns to hunting the rare animal. For the common species, we have $(1-\alpha)(y - w_i/\lambda_L)$. Similarly, $(1-\alpha)(y - w_i/\lambda_L - w_i/\lambda_M)$ is the expected returns from waiting for the rare animal given that a common animal turned up first, multiplied by the probability of this event occurring. For the common species, we have $\alpha(1 - w_i/\lambda_L - w_i/\lambda_M)$.

Strategy S_L (shooting the common animal only) is clearly dominated by S_T (shooting the first animal that arrives). The hunter will choose S_M (shooting the rare animal only) over S_T if the expected returns from waiting

[6] Some villagers have reported that they cannot tell what they are shooting when hunting with guns at night (Ghanaian hunter, personal communication, 2001).

for a rare (more palatable) animal to arrive after a common (less palatable) animal has turned up are less than the certain returns of taking the common animal, that is if $y - w_i/\lambda_M > 1$, and *vice versa*. The hunter will choose S_0 if the expected returns to the best hunting strategy are negative. A hunter will therefore shoot the first animal that turns up if

$$y - \frac{w_i}{\lambda_M} < 1 \quad \text{and} \quad \alpha\left(y - \frac{w_i}{\lambda_M}\right) + (1-\alpha)\left(1 - \frac{w_i}{\lambda_L}\right) > 0, \tag{2}$$

$$\text{which implies } \lambda_M(y-1) \le w_i \le \frac{1}{2}\left(\lambda_M y + \lambda_L\right). \tag{3}$$

Hunters whose individual cost of labour, w_i, is below the lower bound ($w_i \le \lambda_M(y-1)$) will wait for the more palatable animal to turn up and those for whom w_i is above the upper bound ($w_i > 1/2\,(\lambda_M y + \lambda_L)$) will not hunt at all. A simple comparative statics exercise shows that the higher a hunter's opportunity cost of labour, the more likely he will shoot and take home the first animal that turns up rather than wait or shoot and discard, but also the less likely he will hunt.

2.2. Enforcement and cost recovery

Let D be the number of rare animals shot. The regulatory agency's ultimate objective is to ensure that $D = 0$.[7] If this is not possible, it aims to minimize D, subject to its endogenously determined enforcement budget B, which is a function of fine and permit revenue. The agency chooses the price of the permit for hunting the common species, R, and the fine if caught without a permit, G. The fine for hunting the rare species, F, is exogenously determined.[8] The probability of catching a hunter is p, where $p = p(B)$ and $p'(B) > 0$ and $p''(B) < 0$.[9]

This section assumes a discriminating hunter. If hunters cannot discriminate, the only way to ensure that no rare animals are shot is to prevent all hunting. But, in such a case, the regulatory agency would have no income and so preventing all rare animals from being shot is not feasible with non-discriminating hunters and no external budget.

[7] Many conservationists argue that certain species cannot support any level of offtake by hunters (Bowen-Jones *et al.*, 2003).

[8] F is constant for all hunters. Only recently are there examples of fines contingent on an individual's wealth (Bar-Niv and Safra, 2002). If the fine were an unbounded choice variable, enforcement costs could be reduced to zero by setting an infinite fine. Further, excessive fines encourage increased avoidance activities and may not be politically viable (Lear and Maxwell, 1998; Rodriguez-Ibeas, 2002). Following Becker's (1968) framework for optimal enforcement, fines are costless to impose.

[9] The probability that a hunter is caught does not depend on which species he is hunting. Further, a hunter can only be punished if he is in possession of an illegal species and so the time spent before an animal turns up does not affect the probability of being caught, nor does the discarding of an animal after it has been shot. That is, being in the forest with a gun is not in itself an illegal activity. If the hunter could choose how many animals to hunt before returning home, then the time spent hunting could affect the probability of being caught in possession of a dead animal.

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D, the number of rare animals shot, is equal to the number of hunters choosing a strategy of hunting only the rare more palatable species, N_M, plus the proportion of those choosing the strategy of shooting the first animal that turns up for whom the first animal is a rare species N_F. The regulatory agency's optimization can therefore be written

$$\min\{D\} = \min_{R,G}\{N_M + N_F\} \quad \text{s.t. } B \leq B_{\max}. \tag{4}$$

Eight possible strategies, S_{jk}, are available to the hunter: j denotes whether or not the hunter purchases a permit to hunt the less-palatable common species ($j = 1$ or 0 respectively); and k denotes whether the hunter chooses to shoot and keep only the less-palatable common, L, only the more-palatable rare, M, the first animal that turns up, T, or not to go hunting at all, $k = 0$. The hunter chooses the strategy that maximizes his expected returns, V. Taking account of the option the hunter has once an animal turns up, either to take the first animal or wait, his optimization can be written

$$\max E\{V\}$$
$$= \max_{S_{jk}} \begin{bmatrix} -R, & \mathrm{S}_{10} \\ \alpha\left(1-\frac{w_i}{\lambda_L}-\frac{w_i}{\lambda_M}\right)+(1-\alpha)\left(1-\frac{w_i}{\lambda_L}\right)-R, & \mathrm{S}_{1\mathrm{L}} \\ (1-\alpha)\left(1-\frac{w_i}{\lambda_L}\right)+\alpha\left((1-p)y-pF-\frac{w_i}{\lambda_M}\right)-R, & \mathrm{S}_{1T} \\ \alpha\left((1-p)y-pF-\frac{w_i}{\lambda_M}\right)+(1-\alpha)\left((1-p)y-pF-\frac{w_i}{\lambda_L}-\frac{w_i}{\lambda_M}\right)-R, & \mathrm{S}_{1\mathrm{M}} \\ 0, & \mathrm{S}_{00} \\ \alpha\left((1-p)-pG-\frac{w_i}{\lambda_L}-\frac{w_i}{\lambda_M}\right)+(1-\alpha)\left((1-p)-pG-\frac{w_i}{\lambda_L}\right), & \mathrm{S}_{0\mathrm{L}} \\ (1-\alpha)\left((1-p)-pG-\frac{w_i}{\lambda_L}\right)+\alpha\left((1-p)y-pF-\frac{w_i}{\lambda_M}\right), & \mathrm{S}_{0T} \\ \alpha\left((1-p)y-pF-\frac{w_i}{\lambda_M}\right)+(1-\alpha)\left((1-p)y-pF-\frac{w_i}{\lambda_L}-\frac{w_i}{\lambda_M}\right), & \mathrm{S}_{0\mathrm{M}} \end{bmatrix} \tag{5}$$

The regulatory authority can ensure that $D = 0$ if the following conditions hold: if a rare animal turns up first, the hunter waits, whether (C1) or not (C2) he has purchased a permit (expected returns $1 - w_i/\lambda_L$ if he purchased a permit, $1 - p - pG - w_i/\lambda_L$ if not) rather than shoots (expected returns $(1-p)y - pF$); and when a common animal turns up first the hunter shoots, whether (C3) or not (C4) he has purchased a permit (expected returns 1 if he purchased a permit, $1 - p - pG$ if not) rather than waits (expected returns $(1-p)y - pF - w_i/\lambda_M$). An additional condition (C5), that it is better to shoot only the common species with a permit than risk incurring a fine, ensures that conflict is reduced (and in practice eliminates the costs of implementing punishments). In addition, for the hunter to hunt rather than not, the returns to purchasing a permit and hunting the common species

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must be positive (C6). Algebraically, the conditions are written as follows

$$
\begin{array}{ll}
\text{C1: } 1 - w_i/\lambda_L > (1-p)y - pF & \Rightarrow w_i < \lambda_L \beta \\
\text{C2: } (1-p) - pG - w_i\lambda_L > (1-p)y - pF & \Rightarrow w_i < \lambda_L(\beta - p(1+G)) \\
\text{C3: } 1 > (1-p)y - pF - w_i/\lambda_M & \Rightarrow w_i > -\lambda_M \beta \\
\text{C4: } (1-p) - pG > (1-p)y - pF - w_i/\lambda_M & \Rightarrow w_i > -\lambda_M(\beta - p(1+G)) \\
\text{C5: } 1 - w_i/\lambda_L - R > (1-p) - pG - w_i/\lambda_L & \Rightarrow G > Rp - 1 \\
\text{C6: } 1 - w_i/\lambda_L - R > 0 & \Rightarrow w_i < \lambda_L(1-R)
\end{array} \tag{6}
$$

where $\beta = 1 - (1-p)y + pF$.

From the above, clearly if C2 holds, then C1 must also hold, similarly for C4 and C3, and so C1 and C3 need not be considered further. To protect fully the rare species, C2 and C4 must hold for all w_i. Given that $w_i > 0\ \forall\ i$, the problem is only of interest if $\beta > p(1+G)$ and $\beta > 0$, which in turn implies C4 is non-binding and C2 is the binding constraint.

The maximum enforcement budget, $B_{\max}$, and therefore the maximum probability that can be achieved, $p(B_{\max})$, is calculated from the number of hunting permits purchased. If no hunter chooses to shoot a rare animal given this $p(B_{\max})$, then protection of the rare species is indeed compatible with cost recovery and $D = 0$.

Income from the sale of permits, $B_{\max}$, equals the number of potential hunters for whom the net returns to hunting are positive multiplied by the cost of a permit R. From C6, only individuals for whom $w_i < \lambda_L(1-R)$ will hunt

$$B_{\max} = \max\left(0, \frac{(\lambda_L(1-R) - w_{\min})}{w_{\max} - w_{\min}} N \cdot R\right) \tag{7}$$

Equation (7) shows that $B_{\max}$ is quadratic in R ($B''(R) < 0$). If the price of a permit is increased, there are two key effects. First, although the revenue generated per hunter increases, villagers with higher opportunity costs of labour will stop hunting as the expected returns to hunting become negative. Second, for those with lower opportunity costs of labour, hunting the rare species without a permit becomes more attractive relative to hunting the common species with a permit. If the permit price is raised, the probability of being caught required to stop low-cost villagers from hunting the rare species must be higher (marginal deterrence condition).

If no rare animals are to be shot, that is if cost recovery is possible, the following condition for p must hold (setting $G = R/p - 1$ from (C5), substituting into C2 for $w_i = w_{\max}$, and expanding β)[10]

$$p(B_{\max}) \geq \frac{y - 1 + R + w_{\max}/\lambda_L}{y + F} \tag{8}$$

Whether there is indeed some price of the permit for which the government can cover its costs and ensure that no rare animals are shot can conceptually be determined by comparing equations (7) and (8),

[10] A second constraint is imposed on p from the condition that $\beta > p(1+G)$, implying that $p \geq (y-1)/(y-1+F-G)$. However, setting $G = R/p - 1$ implies that $p \geq (y-1+R)(y+F)$. By comparing this expression and equation (8), it follows that the condition in (8) is the relevant one.

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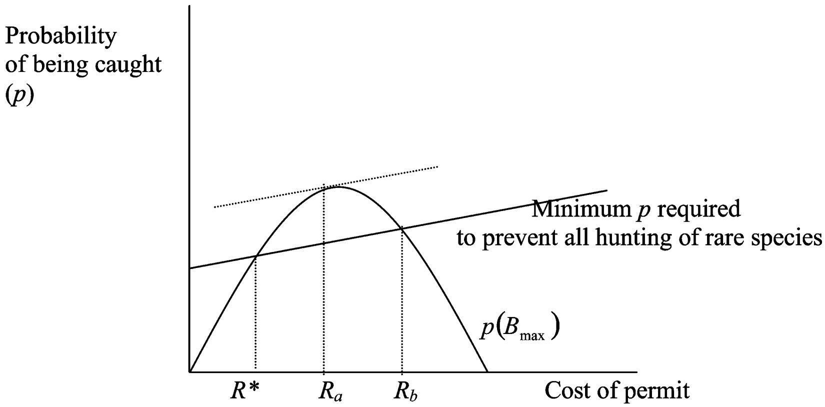

Figure 1a. *Cost recovery consistent with protecting all rare species.*

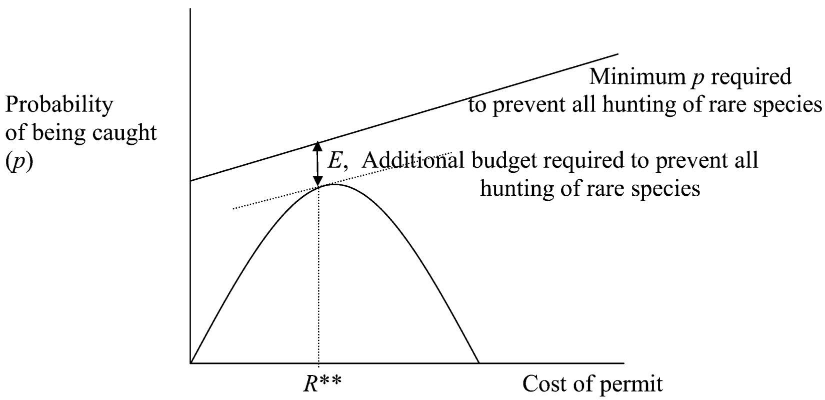

Figure 1b. *Cost recovery not consistent with protecting all rare species.*

demonstrated graphically in figure 1. Figure 1a illustrates a situation in which cost recovery is consistent with protecting all rare animals. Cost recovery is achievable and compatible with protecting all rare animals and relying only on the sale of permits so long as there is more than one species, hunting is discriminatory, and $R^* \leq R \leq R_b$ (see figure 1a). The agency gains surplus revenue if $R^* < R < R_b$. For a regulatory agency interested in both protecting endangered species and maximizing hunter welfare, the optimal permit price is R^*. For revenue maximization, the optimal permit price is R_a.

In effect, the introduction of a hunting permit is equivalent to the agency privatizing a species that was previously an open access resource. If the agency were to set the price of the permit at R_a, it would be exercising an element of market power over wildlife extraction, maximizing its surplus and ignoring the effect that its policy had on the welfare of hunters.[11] If

[11] Niskanen (1971) attributes the growth of the administrative state to such budget-maximizing behaviour by rational bureaucrats.

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the hunters are wealthy foreigners, this might not be of great concern, but the issue is particularly pertinent if the hunters are local villagers whose cooperation and goodwill towards protecting the endangered species is valuable in itself.[12]

If the agency cannot cover all its costs from the sale of permits, the minimum external source of funds required to supplement the sale of permits whilst protecting fully the rare species is E (figure 1b). The agency sets the permit at R^{**} such that

$$\frac{dp(B)}{dR} = \frac{1}{y + F} \tag{9}$$

If no external budget is available, the agency must accept that some rare animals will be shot, in which case the fine revenue collected from those caught can supplement revenue from the sale of permits increasing the probability of detection.

In many countries in west Africa currently fines do little if anything to deter hunting let alone bring in revenue for the authorities. In Ghana fines for hunting protected species such as the civet cat (*Civettictis civetta*) or mona monkey (*Cercopithecus mona*) are 10,000 cedis, approximately US$1.14, yet the market price for these species is about US$11 and US$13 respectively, and the social value likely to be much higher still (Ntiamoa-Baidu, 1997; Damania *et al.*, 2005). Given that average returns to hunting for farmers were approximately equal to the government daily wage in 1976 and 40% greater than average wages in 1993 (Ntiamoa-Baidu, 1997) and that the probability of being caught is low, there are few incentives for farmers to stop hunting or to discriminate over which species they hunt.

Relatively high prices even for the more common species such as cane rats (*Thryonomys swinderianus*) do suggest that there is scope for introducing a revenue-generating permit system. Fines for hunting rare species would have to be increased substantially to well above the market price, as is occurring in Cameroon where the fines for hunting endangered species are being introduced that vary from CFA50,000 to 200,000 (approximately US$100 to 400) in conjunction with the sale of permits for common species (Agnagna and Koutou, 2001). Given that in Cameroon the total annual enforcement budget for the Ministry of Environment and Forests in the 1990s was just US$11,000 supporting 100 staff monitoring a region the size of New York State (Bailey, 2000) such measures should increase considerably the capacity of the country to protect its rare animals.

3. Consequences of non-discriminating hunting

Although the model assumes hunting with guns, in practice a spectrum of technologies is available with different degrees of selectivity. Wire snares are cheap and accessible to most hunters, but are particularly non-selective taking a wide range of animals; traditional traps are more selective – for

[12] Generating revenue over and above that required to protect rare species in a particular protected area might be justified if the additional revenue were used to protect wildlife in other protected areas with less potential for revenue generation.

example, neck traps catch small animals such as cane rats – and other nets more selective still; guns used in daylight are the most selective (Infield, 1998; Bennett and Robinson, 2000).

With enforcement, a non-discriminating hunter will behave in a way similar to the discriminating hunter in terms of the choice of animal carcass taken, but the impact on the number of rare animals killed differs significantly because the non-discriminating hunter will discard any rare animals he kills while waiting for a common animal.[13] Suppose that the enforcement agency is able to recover its costs and ensure that no hunter kills and takes home a rare animal through the strategy described above. If hunters cannot discriminate, the number of discarded rare animals equals the number of hunters multiplied by the proportion who go hunting multiplied by the average number of discarded carcasses per hunter

$$\text{Discarded rare carcasses} = N\frac{\lambda_L(1-R^*)-w_{\min}}{w_{\max}-w_{\min}}\frac{\lambda_M}{\lambda_L} \tag{10}$$

The enforcement agency will not intercept hunters with rare animals and data on the number of hunters intercepted during patrols will not give any clue as to whether or not the enforcement strategy is actually working.[14] Differential enforcement without differential hunting technologies will result in rare animals being killed and discarded and not necessarily showing up in official records. The greater the relative scarcity of the rare animal the less frequently carcasses will be discarded, but the more costly each occurrence will be from a conservation perspective. Similarly, if enforcement is concentrated around traders (where bushmeat is concentrated so enforcement costs might be lower) rather than the hunters, then differential enforcement could simply lead to hunters consuming illegally caught animals and selling those that are legally killed (Damania *et al.*, 2005).

Conceptually, one approach to creating incentives for hunters to adopt more selective yet often more costly hunting technology would be for the cost of the permit to be a function of hunting technology selectivity: the less selective the technology, the more costly the permit. However, this approach in itself raises additional enforcement issues and cannot be considered in isolation from the hunters' opportunity costs of labour.

4. Welfare implications for hunters

Relative to the zero enforcement case, cost recovery in this single-period model reduces hunters' welfare unambiguously because the enforcement agency creates an incentive structure such that only common animals are taken and hunters must pay for permits. In addition, some individuals who would hunt in the zero enforcement scenario no longer find it cost effective.

Because the permit fee results in the economic exclusion of some hunters, λ_L could in fact be treated as an endogenous variable, which is a function of the number of villagers who continue to hunt after a permit scheme

[13] Under the zero enforcement scenario, the non-discriminating hunter will only discard the low value carcass, never the high value carcass and so the number of rare animals killed will be the same whether or not the hunter can discriminate.

[14] In practice, the agency will find some identifiable discarded carcasses.

is introduced, implying also that the implicit value of the permit would also increase. Further, within a multi-period framework an interesting additional benefit from the use of permits to regulate hunting the common species would be revealed. If a permit system was to be introduced in an area where hunting common animals was *de facto* open access, the permit could act akin to a Pigouvian tax, set to manipulate the common species numbers in the long run (increasing λ_L), thereby improving hunter welfare relative to the open access situation by reducing the average time spent hunting. This paper's model could be extended to explore the long-run equilibrium by adding growth functions for the two species and considering how different permit prices affect the long-run number of hunters, their welfare, the long-run equilibrium population of each species, and revenue for the wildlife department (see for example Sutinen and Anderson, 1985; Milliman, 1986; Skonhoft and Solstad, 1996).

5. Concluding thoughts

Enforcement has to be paid for. The strategies available to a government wildlife department depend on the specific country situation, and in most cases are influenced by both the need to protect endangered animals and the impact on the welfare of people who depend on wildlife for their livelihoods. The department will almost inevitably face trade-offs. An optimal permit scheme may neither lead to a social optimum nor result in optimal ecological management. However, in many economically poor countries, the reality is limited budgets and departments must do the best they can.

This paper suggests that protection of endangered species may require the legalization of some hunting, thereby providing the wildlife department with a revenue base for protecting endangered species. Enforcement becomes more complex in such a situation. Firstly, in many countries in west and central Africa most hunting is illegal. A move that permits selective hunting might require greater efforts to explain why some species can be hunted, whereas others cannot. Secondly, exclusion from areas where both the common and rare species are found may no longer be appropriate, making protection of endangered species more difficult.[15] Thirdly, whether or not fine revenue is returned to the specific government agency is critical. If there are problems of corruption, permits may not be purchased if paying a bribe is cheaper and fine revenue will be lower than anticipated.

The introduction of a permit system means that, in practice, the local hunter is paying for the protection of rare and endangered species in return for which he gets the right to hunt the non-endangered species. If such permits cannot raise sufficient income to protect the rare species fully, where there are charismatic species the enforcement agency could introduce trophy hunting. A small number of permits to hunt rare animals are sold and the revenues are used to protect and enhance the number of remaining

[15] In Kenya 'sport hunting' has been banned since 1977; the justification in part being that hunting may be associated with increased poaching (Otieno, 2004). In 2004, Kenya's President Kibaki rejected the Wildlife Conservation and Management Bill that would have reintroduced wildlife 'sport hunting'.

animals and possibly to compensate local residents for loss of hunting rights. The permit price will almost always be considerably more than the maximum fine that can be imposed on local hunters. In Tanzania in 1990, the government earned US$4.5m from hunting licenses (almost exclusively 'trophy' or 'tourism' hunting) and only US$1.9m from the national parks system (Makombe, 1994).[16] However, such a strategy is unlikely to work in west Africa as there are few charismatic species.

The use of hunting revenue to protect resources is not unique to less-developed countries. Burnett (2001: 2) writes that 'in 1908 New York became the first state to require a hunting license. By 1928 every state had instituted a hunting license requirement, with the funds dedicated to wildlife management . . . [Currently in the US] the various licenses, fees and taxes on hunting and hunting equipment fund more than 90 percent of the budgets of state fish and wildlife agencies.'

The requirement of cost recovery is an increasing reality in both poorer and richer countries, with government agencies being required to function as revenue-seeking parastatals rather than relying on externally determined and granted budgets (Nolan and Turbat, 1995). For example, in Canada attention is being paid to cost recovery in natural resources through charging user fees (Natural Resources Canada, 1997). Cost recovery schemes for fisheries are being developed throughout the world, including New Zealand and Australia (Shrank *et al*., 2003; Stokes *et al*., 2006). In poorer countries, the requirement for cost recovery tends to be due both to budget shortages and the desire for improved accountability and macroeconomic stability. In Ghana, the IMF and World Bank have – controversially – proposed privatization and full 'cost recovery' for urban water supplies. Similarly, cost recovery through the introduction of 'user fees' has been introduced in Ghana's health care and education sector, and has been proposed for other sectors.

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[16] The viability of such trophy hunting is also influenced by international conventions such as CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora) and individual country laws, such as the US Endangered Species Act that has recently been relaxed to permit the import of endangered species (Mbaria and Kelley, 2005).

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