Wanted dead and alive:
Are hunting and protection of endangered species compatible?

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Abstract

This paper asks under what conditions it is possible for a wildlife department in west Africa without an external budget to protect all rare and endangered species, and if so, what is the impact on rural inhabitants engaged in hunting. Protecting wildlife in this region is particularly tricky. Hunting is important for rural livelihoods, but when unregulated can result in the loss of species. Government funding for wildlife departments is rarely sufficient and so they must increasingly look towards revenue-generating activities such as the sale of permits for hunting common species combined with fines for those caught with rare species.

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1. Introduction

Increasingly in sub-Saharan Africa, wildlife departments must function in an environment of insufficient government funding. Hence they must look to revenue generating activities to supplement their budgets. In east and southern Africa, many options are available, including tourism and "trophy hunting." Yet in west Africa, the motivation for this paper, the benefits from protecting wildlife, such as protection of biodiversity and existence values, do not naturally translate into income for the department. Most hunting is for meat, undertaken by villagers and professional hunters, thereby generating revenue for the community but not the wildlife department (Bowen-Jones et al, 2003). And there are few "charismatic" species to attract tourists in significant numbers.

A key question for an under-funded wildlife department is to what extent it is able to generate sufficient revenue to protect the country's wildlife, particularly rare and endangered species. And if it is unable, what is the minimum level of external funding required to achieve its objective. A further issue, critical from a livelihoods perspective, is the impact that any revenue-generating activities undertaken by the wildlife department have on the livelihoods of rural people who are highly dependent on the natural resource base, including access to wildlife as a source of both food and income.

In general, the major expense for a wildlife department is enforcement, protecting wildlife from local and professional hunters. Hence this paper uses as its theoretical framework an optimal enforcement model. The fundamental issues for law enforcement were posed by Becker (1968). He asked how many offenses should be permitted, and how many offenders should go unpunished. Typically in the literature the enforcement agency aims to maximize social welfare. Because enforcement is costly, and particularly when individuals choose between different crimes or different levels of a criminal activity, in equilibrium it is optimal to have both a positive level of enforcement and a positive level of the illegal activity (see, for example, Stigler, 1970; Sutinen and Andersen, 1985; Milliman, 1986; Clarke, Reed, and Shrestha, 1993).

Wildlife departments can consider scope for revenue generation through a mix of fines, registration fees, and the sale of permits. When cost recovery is an objective, fines can no longer be considered simply transfers from the individual caught undertaking an illegal activity to the enforcer – as is the typical assumption in the optimal enforcement literature. Rather, fines for those caught with rare species, along with revenues from the sale of hunting permits, become key potential revenue sources. The sale of permits for hunting also implies the legalization of hunting activities that might previously have been illegal. Moreover, again in contrast to the standard literature, under conditions of cost recovery, the probability of detection is unlikely to be independent of the level of the fine.

Cost recovery is a reasonable objective when the social returns to an activity are no greater than the private. However, if this is not so, as is the case for a wildlife department, the revenues generated from enforcement may not cover the costs of the socially optimal level of enforcement. Polinsky (1980) concluded that under such circumstances private enforcement – in which the profit-maximizing enforcement agency aims to maximize fine revenue less the cost of enforcement – may not be appropriate (see also Landes and Posner, 1975; Garoupa, 1997). However the implications of cost recovery, rather than simply a comparison of private and socially optimal enforcement, have not been explored.

This paper asks specifically whether a wildlife department can hope to prevent all rare animals from being shot when constrained by the need to recover its costs. This is, for many policy makers with constrained budgets, the key practical question. The paper also looks explicitly at the impact of such a policy of cost recovery on the welfare of villagers for whom hunting is an important source of income and food. Reducing conflict between those who protect resources and those who use resources is increasingly important, as the enforcement paradigm shifts from interdiction and control towards more conciliatory approaches (Bowen-Jones et al, 2002). The paper does not seek to calculate the socially optimal level of enforcement. The mathematics of such a question is a relatively simple unconstrained optimization model, and many such models can be found in the enforcement literature (examples include Demsetz, 1964; Stigler, 1970; Milliman, 1986, Shavell, 1993).

Where cost recovery is not consistent with protecting all rare species, then either a subsidy is required in the form of an external budget, or the wildlife department and society must accept the loss of rare animals. Hence this paper is also relevant for a conservation-oriented agency in terms of the extent to which it can fulfill a remit to protect endangered species with a fixed budget that can be supplemented with revenue from fines and the sale of permits. Full cost recovery simply implies that the external budget is zero.

In the following section, a model of hunting is developed that explores the feasibility of cost recovery when hunting technology is sufficient for hunters to choose which species they shoot.[1] The implications of non-selective hunting and enforcement technologies are explored in Section 3. Finally, the policy implications of the model are discussed in Section 4.

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[1] There is some skepticism as to whether such selectivity is possible, but certainly people who hunt with guns in the daytime can, if they so choose, be selective. See Bowen-Jones et al (2003) for a more detailed discussion.

2. Model

Hunting is complex, and this paper does not purport to model specific hunting behavior in detail. However, a few details about hunting are useful to motivate the model. In west and central Africa, people hunt wildlife typically for meat, which is either consumed by the hunter or sold. Both vulnerable and common species are often found in the same geographical location, and so the only alternative to complete exclusion, even if it were possible, is selective hunting (Bowen-Jones et al, 2003).

Selective hunting can only be achieved if both the technology is available and the incentives are appropriate. Snares are relatively non-discriminatory in terms of which animals are caught, though some snares are designed to differentiate between large and small animals. However, increasing the frequency that a snare is checked increases the likelihood that a rare animal is found alive in the snare and so can be released thereby increasing the effective selectivity. Hunting with guns is more discriminatory. Hunters typically can identify different species from a distance and could, in theory, choose whether or not to shoot a particular animal.

In the model, a large number of risk-neutral hunters, identical in all respects except for their opportunity costs of labor, live in and around a forested area. The model permits a single hunting expedition, which can be of varying length, in which a hunter can only shoot one animal, after which he returns home.[2] A regulatory agency is

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2 The hunting period is assumed to be considerably less than the reproductive cycle of either species. Further, the emphasis of the paper is on cost recovery and not the detailed modeling of population dynamics, hence the focus on a single hunting expedition where only one animal is shot. Alternative hunting strategies observed by the author in Ghana include: hunt until you can carry no more bushmeat; until you run out of provisions; or until you run out of bullets. On-going research addresses multiperiod issues, including a growth function for the bushmeat species, and permitting hunters to choose how many

responsible for the wildlife in the forest. There are two types of animal that, from the hunters' perspective, are more or less valuable when sold as bushmeat, the price being driven by consumer preferences. From the regulatory agency's perspective, the two types of animals are rare and hence socially valuable, or common, in which case they have no value over and above their value as bushmeat. The key potential revenue sources available to the wildlife department are the sale of hunting permits, and fines for those caught hunting illegally.

The regulatory agency's objective is to minimize the number of rare animals that are killed, subject to a budget constraint, with a secondary concern being the welfare of hunters. In this cost recovery model, 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 permits. Conceptually, fines could be imposed on hunters caught with rare or common species, and similarly hunters could be required to purchase permits for hunting both or either the rare and common species. For the purposes of this paper, and to avoid lengthy less interesting reformulations of the model, permits are sold only for hunting the common species. Fines are imposed on hunters who are caught with a rare animal, or with a common animal without a permit. The maximum fine that can be imposed is F, a common assumption in the literature, else the enforcement agency could reduce the cost of enforcement to zero by setting an infinite fine.[3] Further, fines

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animals to shoot and hence when to stop hunting in any given period. The assumptions of the model in this paper enable analytical tractability whilst not compromising the key contribution of the model.

[3] Moreover, a fine typically will be capped by the wealth of the individual who is caught. Although different hunters will in reality have different levels of wealth, for ease of calculation F is assumed constant for all hunters. Not only is this the common assumption in the optimal enforcement literature. In practice, only recently, and only in

considered excessive encourage increased avoidance activities and may not be politically viable (see, for example, Lear and Maxwell, 1998; Rodriguez-Ibeas, 2002). Following Becker's (1968) framework for optimal enforcement, fines are assumed costless to impose.

The government could generate revenue by also make the hunting of common species illegal, and fining those caught with a common species. However, for a government also concerned with the welfare of village hunters, the more satisfactory approach is that explored in this paper, to combine the sale of permits for those who want to hunt the common species with fines for those who are caught either with a rare species or with a common species but without a permit.

When the common species is also the more palatable species, for example, in some parts of Ghana cane rat is a common vermin species yet the most preferred bushmeat species, the government's job is relatively easy. The government wants to protect the rare less-palatable species and the hunter would prefer to shoot the common more-palatable species (Bowen-Jones et al 2002). The more interesting scenario, and hence the focus of this paper, is that in which the rare animal is also the more palatable, in which case conflict is more likely because the scarce more-palatable animal is valued highest by both the government (when the animal is alive) and the hunter (when the animal is dead). One such example is the drill in Cameroon, which is both endangered and a preferred bushmeat species. In cases where animals and birds are sold live, almost always the most privately valuable species will also be the most endangered species.

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some countries, are there examples of fines being contingent on an individual's wealth (Bar-Niv and Safra, 2002).

2.1 The individual hunter

The hunter's objective is to maximize his expected net revenues from hunting. A Poisson arrival process is used to model 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), denoted by the subscript *L*, arrive at a rate λ_L. Hence the probability, α, that a more palatable animal arrives first is $\lambda_M/(\lambda_M + \lambda_L)$ and the probability, 1-α, that a less palatable arrives first is $\lambda_L/(\lambda_M + \lambda_L)$. Hunters are assumed to be accurate – if they shoot, they do not miss.

There are seven possible strategies available to the hunter, listed in Table 1, and denoted by S_{jk}, where *j* denotes whether or not the hunter purchases a permit to hunt the less-palatable common species (*j=p* or *0* respectively), and *k* denotes whether the hunter chooses to hunt only the less-palatable common, *L*, only the more-palatable rare, *M,* or the first species that turns up, *F*. The hunter can also choose not to go hunting, *k=0.* The probability of being caught is written *p*, where *p* is a function of the enforcement budget *B* ($p'(B)>0$ and $p''(B)<0$).[4] 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); hunter *i*'s opportunity cost of labor is w_i; the cost of a permit is *R*; the fine for not having a permit when shooting the common animal is *G*, and for hunting the rare species is *F*.

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[4] 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, hence the time spent before an animal turns up does not affect the probability of being caught. 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.

An individual hunter faces uncertainty over the returns to hunting because he does not know when an animal will turn up and, if he is hunting illegally, whether or not he will be caught. The agency faces no uncertainty since there are a large number of hunters. Hence the agency knows how its choice of enforcement effort will affect hunting decisions and hence the number of rare species shot.

For the regulatory agency to achieve its objective of preventing any rare species from being shot, it must ensure that, whether or not a hunter purchases a permit, he only shoots the common animal. That is, if a common animal turns up first, the hunter shoots it, and if a rare animal turns up first, he waits for a common animal. To reduce conflict, and in reality to reduce also the costs of implementing punishments, the agency also would want people to purchase a permit when hunting the common species, rather than risk incurring a fine.

If no rare species are shot and all hunters purchase a permit, five conditions C1 through C5 must hold (Table 2). These can be reduced to the following three statements: (1) If it is worthwhile for an individual to hunt, he chooses whether or not he purchases a permit; (2) If a less palatable animal turns up, whether he shoots or "gambles" and waits for a more palatable animal; and (3) If a more palatable animal turns up whether he shoots or "gambles" and waits for a less palatable animal.

A hunter who does not purchase a permit will hunt only the common species so long as conditions C4 and C5 hold, that is, so long as:

$$w_i < \lambda_L(\beta - p(1+G)) \text{ and } w_i > -\lambda_M(\beta - p(1+G)) \qquad (1)$$

Only one of these conditions will be binding.

To ensure that individuals who choose to hunt only the common animal purchase a permit, condition C3 must hold:

$$G \geq R/p - 1 \tag{2}$$

If condition C4 holds, then C1 must also hold. Similarly, if C5 holds, then C2 must also hold.

2.2 Aggregate hunter behavior and the government's optimal strategy

To determine the aggregate hunting behavior, assumptions over the number of potential hunters and their opportunity costs of labor are required. Suppose there are N potential hunters whose opportunity costs of labor vary uniformly between $w_{\min}$ and $w_{\max}$. The assumption of such heterogeneity among hunters is a reasonable one in a rural village setting where land and labor markets do not function efficiently, where some hunters are also farmers who hunt only at certain times of the year, and where some people get positive utility simply from going out hunting. A simple uniform distribution enables analytical tractability without compromising the model and its findings.

The model is solved in the following way. First it is assumed that cost recovery and full protection of endangered species can be achieved. That is, that the five key conditions C1 through C5 hold for all hunters. The implied maximum enforcement budget, $B_{\max}$, and hence the maximum probability that can be achieved, $p(B_{\max})$, is then calculated, given these conditions. If no hunter chooses to shoot a rare species given this maximum probability of detection, then protection of rare species is indeed compatible with cost recovery.

If the five conditions C1 through C5 hold, income from the sale of permits, and hence the maximum budget available for enforcement, is equal to the proportion of hunters for whom the net returns to hunting are positive, multiplied by the number of potential hunters *N* and the cost of a permit *R*. That is, the maximum enforcement budget is given by:

$$B_{\max} = \max\left(0, \frac{(\lambda_L(1-R) - w_{\min})}{w_{\max} - w_{\min}} N \cdot R\right) \tag{3}$$

Equation 3 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 labor will stop hunting as the expected returns to hunting become negative (villagers will only hunt if condition C6 holds). Second, for those with lower opportunity costs of labor, hunting the rare species without a permit becomes more attractive relative to hunting the common species with a permit. Hence if the permit price is raised, the greater the probability of being caught that is required to stop low-cost villagers from hunting rare species (marginal deterrence condition).

More formally, if no rare species are to be shot, the following two conditions for p_i must hold (setting $G = R/p - 1$ (C3), substituting into C4 and C5, and expanding β as $(1-(1-p)y + pF)$):

$$p_i > \frac{y - 1 + R + w_i/\lambda_L}{y + F} \text{ and } p_i > \frac{y - 1 + R - w_i/\lambda_M}{y + F} \tag{4}$$

Only the first condition is binding.

Whether there is indeed some price of the permit for which the government can cover its costs and ensure that no rare species are shot can be determined by comparing

Equations 3 and 4. These conditions are demonstrated graphically in Figure 1. Figure 1a illustrates a situation in which cost recovery is consistent with protecting all rare species, and Figure 1b a situation in which it is not. In the latter case, the minimum external budget E required to supplement the sale of permits whilst protecting the rare species is also shown.

Algebraically, cost recovery is possible so long as:

$$p(B_{\max}) \geq \frac{y - 1 + R + w_i / \lambda_L}{y + F} \tag{5}$$

Cost recovery is achievable and compatible with protecting all rare species and relying only on the sale of permits so long as $R^* \leq R \leq R_b$ (see Figure 1a). And the agency achieves cost recovery and gains surplus revenue if $R^* < R < R_b$. The optimal permit price depends on the agency's particular objective. Initially, increasing the price of the permit above the minimum permit price R^* reduces hunter welfare because permit prices are higher and more hunters stop hunting, but increases the agency revenue over and above that needed for cost recovery, providing the agency with a surplus. However, if R is increased above R_a, both agency excess revenue and hunter welfare decrease. 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.

If cost recovery and protection of all rare species is not possible, a regulatory agency with access to an external budget sets the permit level to be R^{**} (Figure 1b) such that:

$$\frac{dp(B)}{dR} = \frac{1}{y + F} \tag{6}$$

Permit revenue is supplemented with an external budget of size E (Figure 1b). If no external budget is available, then the agency must accept that some rare species will be shot, in which case it can use the fine revenue collected from those caught shooting the rare species to supplement revenue from the sale of permits and so increase the probability of detection.

3. The implications of non-selective hunting technology

If hunters are not able to be selective when hunting, then differential enforcement will have a very different impact. Such a scenario is realistic if, for example, hunters use non-selective snares that are only checked every three or four days at which point the snared animal is already dead. Some hunters who use guns have reported that they cannot tell what they are shooting when they hunt at night, though such a suggestion is controversial (personal communication, Ghana, 2001; Bowen-Jones et al, 2003).

With differential enforcement, hunters who cannot be, or choose not to be, selective must, once an animal is dead, choose whether to take it but risk being caught with an illegal carcass, or discard it and wait for another animal to turn up. That is, these hunters do not choose which species they kill, but they can choose to discard a dead animal – either it is low value or there is a high probability of being fined. Hence differential enforcement, when hunting does not allow selectivity, could result in significant waste, with rare animals being killed and discarded. Moreover, the incentives to purchase a permit to hunt the common species would be reduced, thus reducing the department's revenue. Equally, if enforcement is concentrated around traders (where bushmeat is concentrated) rather than the hunters, then differential enforcement could simply result in hunters consuming illegally caught species and selling those that are legal.

4. Concluding thoughts

Enforcement has to be paid for. If a government wildlife department does not have an external budget, or if the external budget is insufficient for the department to achieve its objectives, then it will have to look to revenue-generating activities to supplement the budget. The strategies available to the department will depend on the specific country situation, and will in most cases be influenced by both the need to protect endangered species and the impact of its strategy 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 less-developed countries, the reality is one of limited budgets and departments must do the best that 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, if not all, hunting is illegal. A move that permits selective hunting might encourage people to see hunting in general as acceptable, and so greater efforts would be needed to explain why some animals can be hunted whereas others cannot. Secondly, exclusion from areas where both the common and rare species are found may no longer be appropriate. For example, hunters may be allowed to enter areas where endangered species are prevalent, making protection of these species more difficult. 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, hence fine revenue to the agency will be lower than anticipated.

The introduction of a permit system means that, in practice, the 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 permits cannot raise sufficient income to protect the rare species from hunters, and no external budget is available, then the enforcement agency must either supplement its income with fine revenue, or where feasible, could introduce so-called trophy hunting, which brings in large funds that can be used for wildlife protection and to compensate local residents for loss of hunting rights. A small number of rare animals are killed to raise funds to protect and enhance the number of remaining animals. The trade-off is between explicitly allowing the killing of rare animals as "trophies," and accepting that some will be killed illegally. The amount paid by those who trophy hunt, typically wealthy foreigners, will almost always be considerably more than the maximum fine that can be imposed on those local poachers that are caught. However, there are moral, reputation, and international treaty implications of legitimizing the hunting of rare species. In west Africa, such a strategy is unlikely to work, as most hunting is for meat and there are few charismatic species. Moreover, by definition, the government could not achieve its objective of no rare animals being shot.

Both hunting technology and the 'technology of enforcement' are critical in determining whether selective hunting is possible, and the impact of enforcement on species numbers. One of the key problems at the moment for those involved in attempting to regulate the bushmeat trade is that hunters are rarely selective. This is in part because the enforcement incentives are not appropriate, and hunters are rarely caught and punished, but also because the technology is not sufficiently selective. Selective hunting is more costly. Checking traps more frequently may be difficult if people are also farmers, in which case, they often do not make specific trips to check the traps but rather check the traps when they are also undertaking farming activities. Choosing not to shoot a rare animal means spending more time hunting, which is also more costly. Hence not surprisingly, achieving differential hunting in practice is not simple. However, this paper demonstrates the conditions under which incentives are such that hunters might be expected to be selective in their hunting.

Examples of more sophisticated “enforcement technology” can be found. One such is the use of fishing permits which state that fish within a particular size range (those that breed more productively) must be released. Similarly, prohibiting the killing of pregnant animals should have a positive impact on populations, achievable, for example, through the introduction of hunting seasons.

This paper used a single period model to explore cost recovery. Within a multi-period framework, an interesting additional benefit from the use of permits to regulate the hunting of common species is revealed. If a permit system was to be introduced in an area where hunting common species was *de facto* open access, the permit could act akin to a Pigouvian tax, increasing the cost of hunting the common species. In a single-period analysis, permits appear to reduce hunter welfare. However, the price of a permit could be set to manipulate common species numbers in the long run, thereby improving hunter welfare relative to the open access situation.

The requirement of cost recovery is an increasing reality in less-developed countries, and hence the analysis of this paper has more general implications. Government agencies are being required to function as revenue-seeking parastatals, rather than relying on externally determined and granted budgets (Nolan and Turbat, 1995). This requirement of cost recovery is due both to budget shortages and the desire for improved accountability and macroeconomic stability. In Ghana, the IMF and World Bank have proposed privatization and full “cost recovery” for urban water supplies. But such a policy is controversial, especially when there are benefits associated with the supply of a resource that are not reflected by the market. Similarly, cost recovery through the introduction of "user fees" has been introduced in Ghana's health care and education sector, and has been mooted for other sectors.

Table 1: Returns to hunting strategies

Hunter strategy		Expected returns to strategy for given probability of detection p
S_{00}	Do not hunt (and do not purchase a permit)	0
S_{PL}	Purchase a permit and shoot only the common species	$1-\frac{w_i}{\lambda_L}-R$
S_{PF}	Purchase a permit and shoot the first animal that turns up	$(1-\alpha)\cdot\left(1-\frac{w_i}{\lambda_L}\right)-R+\alpha\cdot\left((1-p)y-pF-\frac{w_i}{\lambda_M}\right)$
S_{PM}	Purchase a permit and shoot only the rare species	$(1-p)y-pF-\frac{w_i}{\lambda_M}-R$
S_{0L}	Do not purchase a permit and shoot only the common species	$(1-p)-pG-\frac{w_i}{\lambda_L}$
S_{0F}	Do not purchase a permit and shoot the first animal that turns up	$(1-\alpha)\left((1-p)-pG-\frac{w_i}{\lambda_L}\right)+\alpha\cdot\left((1-p)y-pF-\frac{w_i}{\lambda_M}\right)$
S_{0M}	Do not purchase a permit and shoot only the rare species	$(1-p)y-pF-\frac{w_i}{\lambda_M}$

Table 2: Conditions for hunter to adopt a strategy of purchasing a permit and shooting only the common animal

Condition*			Explanation
C1: $1-w_i/\lambda_L > (1-p)y - pF$	$\Rightarrow$	$w_i < \lambda_L \beta$	If a rare animal turns up, the hunter who has purchased a permit will wait for the common animal
C2: $1 > (1-p)y - pF - w_i/\lambda_M$	$\Rightarrow$	$w_i > -\lambda_M \beta$	If a common animal turns up, the hunter who has purchased a permit will shoot rather than wait for the rare species
C3: $1-w_i/\lambda_L - R > (1-p) - pG - w_i/\lambda_L$	$\Rightarrow$	$G > R/p - 1$	It is better to hunt only the common species with a permit than without
C4: $(1-p) - pG - w_i/\lambda_L > (1-p)y - pF$	$\Rightarrow$	$w_i < \lambda_L(\beta - p(1+G))$	If the hunter does not purchase a permit and a rare species turns up first, it is better to wait for the common species to turn up
C5: $(1-p) - pG > (1-p)y - pF - w_i/\lambda_M$	$\Rightarrow$	$w_i > -\lambda_M(\beta - p(1+G))$	If the hunter does not purchase a permit and a common species turns up first, it is better to shoot the common animal than wait for a rare animal
C6: $1-w_i/\lambda_L - R > 0$	$\Rightarrow$	$w_i < \lambda_L(1-R)$	Non-negativity constraint, it is better to purchase a permit and hunt common than not go hunting

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

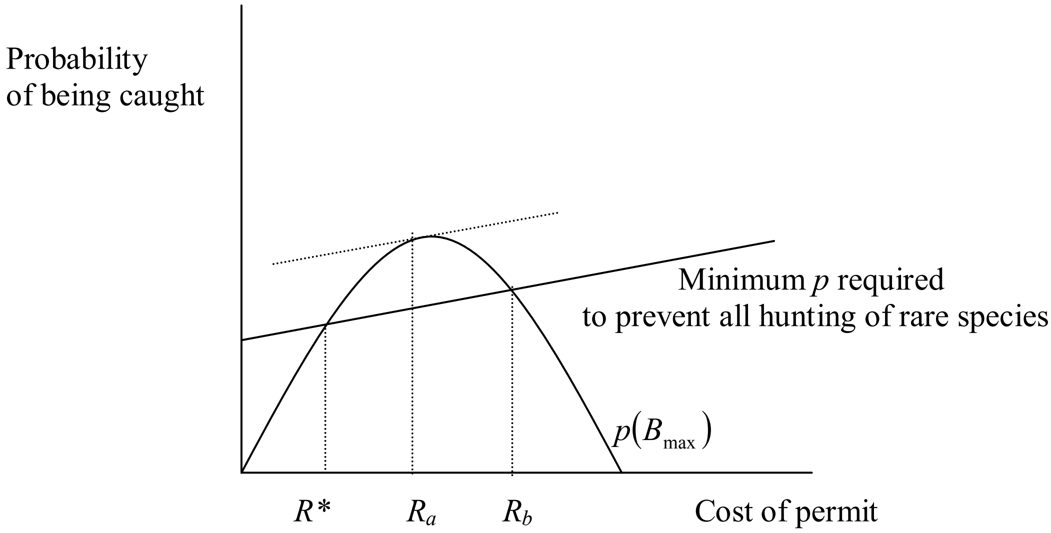

Figure 1a: Cost recovery consistent with protecting all rare species

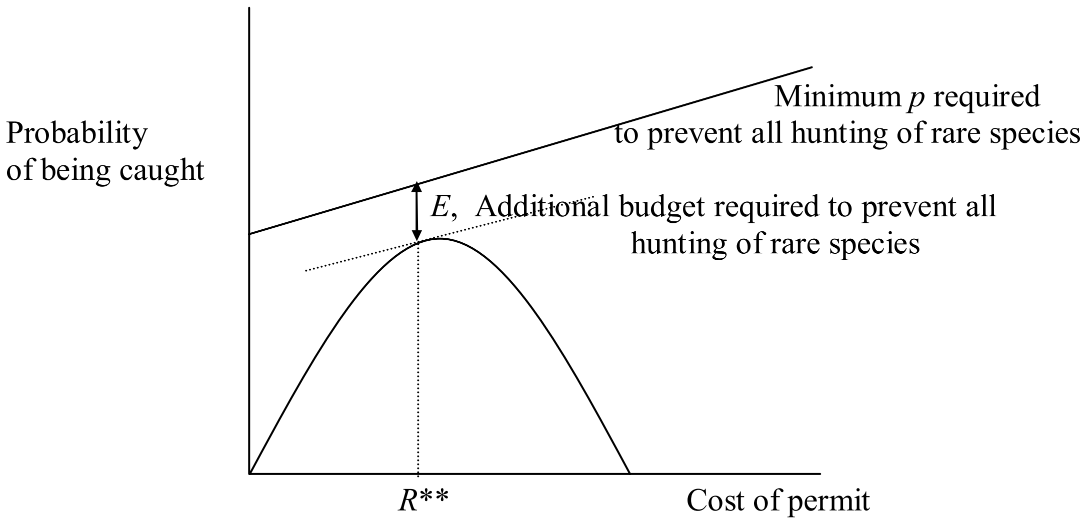

Figure 1b: Cost recovery not consistent with protecting all rare species

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