The Poacher's Dilemma: The Economics of Poaching and Enforcement

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Abstract

In April 2000, delegates gathered in Nairobi, Kenya, to consider the worldwide ban on ivory trade governed by the Convention of International Trade in Endangered Species of Wild Fauna and Flora (CITES). A point of contention during the meeting was the inequity created by a uniform ivory trade policy, given the significant differences in the size and health of elephant populations in several African countries. Ultimately, South Africa, Botswana, Namibia, and Zimbabwe backed away from their efforts for limited ivory trade and, on April 17, 2000, the delegates agreed to reinstate a ban on ivory trade. A similar ban on the trade of rhino horns has been in place since 1977. This paper looks at alternatives to these one-size-fits-all international trade bans for ivory and rhino horns and explores the economics of the decision-making process of poachers under strict enforcement policies. By understanding poacher's decision-making process, local officials can design anti-poaching policies that can optimize conservation given local conditions. First, this paper provides a brief background on poaching activity in Africa and describes some successful examples of anti-poaching policies. Second, it develops an expected utility model for an individual poacher. This model illustrates the key factors in the poacher's decision-making process. Third, this theoretical model is slightly modified to examine the effects of corruption. Fourth, several of the key assumptions and variables of the model are discussed including the value of a statistical life and the overestimation of low probability events. Finally, the paper offers some concluding thoughts.

Brief history of poaching in Africa

From the 1970s through the early 1990s, the international community became increasingly concerned about the illegal poaching of African elephants (*Loxodonta africana*) and rhinos (Rhinocerotidae). Since the 1970s, the population of African elephants has declined from 1.2 million to approximately 600,000 (Table 1) (Bulte and van Kooten 1999). As the population of large bull elephants decreased, poachers began to take aim at female elephants and adolescents. From 1979 to 1988, twice as many elephants were needed to be killed for each ton of ivory (Chadwick 1991).

During this period, rhino populations experienced an even more dramatic decline. In Africa, the population of black rhinos (*Diceros bicornis*) (Table 2) was 65,000 in 1960, but shrank to 6,000 by 1985. It is currently around 2,000 (Swanepel 1997; Emslie 1996). In Zimbabwe, the population of rhinos decreased from at least 5,000 in the 1960s to essentially zero (only in zoos) in 1990. Only four African countries still have viable rhino populations: South Africa, Zimbabwae, Namibia, and Kenya (Emslie 1996).

These increases in poaching activity paralleled the dramatic increases in the price of ivory and rhino horns. In 1969, uncarved ivory in Kenya was worth $2.50 per pound. In 1978, it was worth $34 per pound and, in 1989, it was worth more than $90 (Figure 1). With tusks weighing as much as 22 pounds each, this made

Table 1. Current African Elephant Population (Overton 1997). Note that "Definite" and "Probable" estimates come from more reliable aerial and dung counts. "Possible" and "Speculative" are based on more general 'guesswork.'

Region	Definite	Probable	Possible	Speculative
Central Africa	7,320	81,657	128,648	7,594
East Africa	90,468	16,707	19,999	1,084
Southern Africa	170,837	16,402	18,983	21,582
West Africa	2,760	1,376	5,305	5,554
Continental	**286,234**	**101,297**	**155,944**	**36,057**

Table 2. Black Rhino Population (Swanepoel 1997).

Year of Count	Estimated Rhino Population	Projected Number of Rhinos Killed
1900	10,000	n/a
1960	70,000	500
1970	65,000	500
1981	10,000-15,000	4,545-5,000
1987	3,800	1,033-1,867
1995	2,200	200

one elephant's ivory worth as much as $4,000 (Simmons and Kreuter 1989). A rhino horn can weigh up to 20 pounds. The retail price for an African rhino horn has ranged from $2,000 to $8,000 per pound (Vollers 1987; Simmons and Kreuter 1989). Estimates of the value of ivory and rhino horn vary widely. Presumably, some of the difference in value is between the wholesale and retail levels, as well as the difference between carved and uncarved pieces. It was estimated, that when the prices for ivory and rhino tusks were at their peaks in the 1980s, a successful hunt could yield a poacher more money than twelve years of non-poaching work (Chadwick 1993).

In response to growing international concern about the illegal poaching in Africa, CITES banned the worldwide trade in rhino horns in 1977 and banned trade in ivory in 1989. While the ivory ban seems to have slowed the rate of poaching and lowered the price of ivory, the population of African elephants has continued to decline, albeit at a slower rate. Since 1994, Bulte and van Kooten (1999) estimated an annual decline of 0.5-0.6 percent. Without poaching, elephant populations increase by an average of 5 percent per year. During the first four years of the ivory trade ban, the price declined by more than 70 percent from its 1989 peak. The price of ivory in central Africa dropped from $90 per pound to less than $10 per pound (Kelso 1993). However, in the years since the ban, the price has slowly climbed.

One of the primary problems with the ivory ban is its impact on southern African countries, which have growing elephant populations that require periodic culls to limit ecological damage. Not only do these southern African countries sometimes have too many elephants, but the ivory ban has also taken away a source of precious foreign currency; currency, that the government claims would be used, in part, for conservation efforts. In response to these concerns, in 1997, delegates at the Conference of the Parties for CITES permitted a one-time auction of ivory stockpiles for Zimbabwe, Namibia, and Botswana. In April 1997, this auction was held. A total of 109,311

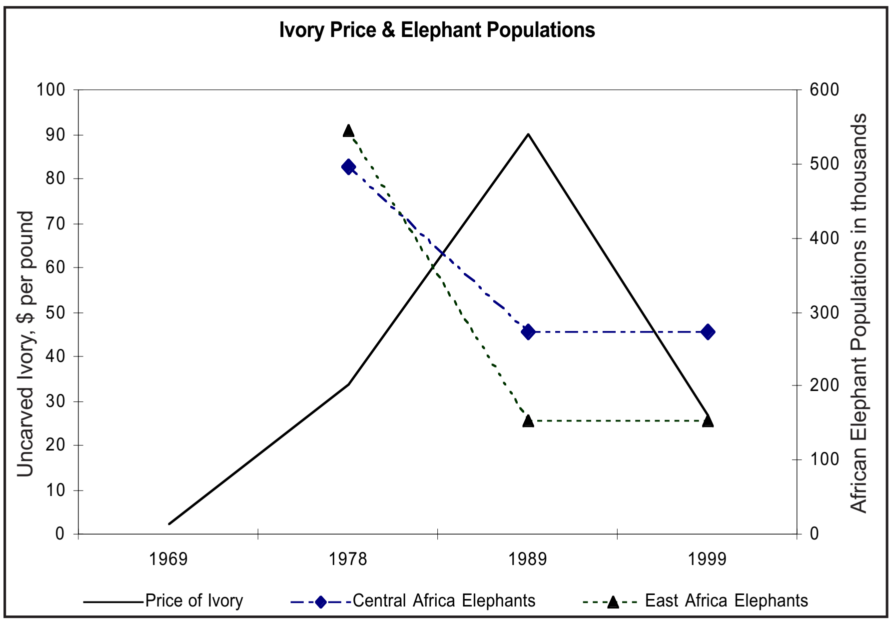

Figure 1. Longitudinal comparison of African elephant populations and the price of ivory.

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Cover: Rhinoceros auklet (*Cerorhinca monocerata*). Photograph courtesy of Julie Thayer.

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pounds of ivory (5,446 tusks) was sold for an estimated $5 million (approximately $45 per pound). Before this auction, southern African countries had an estimated stockpile of 500-600 tons of legally held ivory. An additional 243 tons of illegal stockpiles are also extimated to exist (Milliken 1997). Approximately 8,000 elephants have to be killed to obtain 70 tons of ivory (*The Economist* 1989).

No such controversy exists for the trade in rhinoceros horns as rhinos remain on the Appendix I for the CITES meaning that trade is banned. However, poaching of rhinos continues primarily to supply horns to lucrative markets in Yemen (as dagger handles) and China (as medicines).

While most African countries outlaw the killing of elephants and rhinos, especially in national parks and protected areas, in reality these laws have been poorly enforced. Anti-poaching units tend to be severely under-funded, corrupt, and are often out-gunned by poachers (Simmons and Kreuter 1989). However, examples exist where individual countries have successfully fought poaching and nurtured a growing population of elephants and rhinos. A commonality in these "success" stories is a willingness to use lethal force to enforce anti-poaching laws combined with some type of Integrated Conservation and Development Program (ICDP) that tries to raise the non-poaching wage rate (see Brandon et al. 1998; Wells and Brandon 1992; Barrett and Arcese 1995 for a more complete discussion of ICDPs). Lethal "shoot first; ask questions later" policies (also known as "shoot-to-kill" and "shoot on sight") can offend humanistic ethical sensibilities, especially over the lack of due process and the idea that the punishment should be proportional to the crime. In other words, should the penalty for illegally killing an elephant or rhino be the death of a human? The ethics of these policies will be discussed later.

Several instances exist where lethal anti-poaching policies have been used in combination with economic development programs. In 1984, Zimbabwe instituted "Operation Stronghold," a "shoot first" policy to protect rhinos and elephants. As a result of these enforcement, in 1992, only 46 elephants were poached compared to 4,000 in 1989 (Kelso 1993). The Zimbabwean elephant populations grew from 30,000, in 1979, to 43,000 by 1989 (Simmons and Krueter 1989). Similarly, the Zimbabwean rhino population has also rebounded from almost nothing to at least 260 in 1997 (Economist 1997).

Strict enforcement in Nepal has yielded similar results. The rhino population in Nepal has rebounded from as few as 96 rhinos in 1968 to an estimated 550 by late 1997, since the King of Nepal committed units of the army to protect the rhino population (Martin 1998; Martin and Vigne 1995; Starr 1989). Likewise, during Richard Leakey's tenure as Director of the Kenya Wildlife Service, the initiation of a "shoot first" policy resulted in a reduction of the number of elephant deaths due to poaching. Since then, Kenya's elephant population has been increasing at rate of 2.6-4.0 percent (Woods 1999). The black rhino population in Kenya's Masai Mara National Reserve increased from less than 13 rhinos in 1986 to approximately 40 in 1997 (Morgan-Davies 1996).

However, these anti-poaching policies involve the loss of human life. During the first decade of Operation Stronghold, more than 178 suspected poachers were killed (Kelso 1993). Similarly, in Kenya more than 100 poachers were killed during the first two years of a "shoot first" policy (Chadwick 1993).

The Poacher's Dilemma: Model Equations

(1) $$\max EU = [1 - r_d(G) \times t_p] \times U(C)$$

(2) $$w \times t_w + P_E \times E(t_p) + P_R \times R(t_p) + S - r_f(G) \times F - C = 0$$

(3) $$T = t_p + t_w$$

(4) $$\frac{r_d(G)}{[1 - r_d(G) \times t_p]} \times \frac{U(C)}{U'(C)} + w + r_f(G) \times F = P_E E' + P_R R',$$

where $0 < r_d(G) \times t_p < 1$

(5) $$w + B = P_E E' + P_R R'$$

Poacher's dilemma

A poacher's decision on how much time to spend hunting can be shown by an expected utility model. An expected utility model is commonly used in economics and incorporates key factors that influence an individual's decisions and actions. To understand the model, refer to the model notation on the following page.

The poacher must decide the amount of time spent poaching rela-

The Poacher's Dilemma: Model Notation

C	**=consumption**
U(C)	**=lifetime utility**
t_p	**=time spent poaching**
$r_d(G) \times t_p$	**=risk of death per hour†**
$r_f(G) \times t_p$	**=risk of fine per hour†**
t_w	**=hours worked**
w	**=wage income**
$E(t_p)$	**=number of elephants killed***
$R(t_p)$	**=number of rhinos killed***
S	**=unearned income**
F	**=amount of fine**
T	**=time**

*Increases with time spent poaching
†Increases with government enforcement and time spent poaching
Note: primes (') represent derivatives

tive to the amount of time spent in wage employment given the respective risks and rewards. Utility is a broadly defined term roughly synonymous with welfare, satisfaction, and happiness. In this expected utility model several variables are included that affect a poacher's decision on how much time, if any, should be devoted towards poaching.

Equation 1.
A poacher's maximum expected utility, EU, comes from his/her consumption during his/her lifetime, $U(C)$, minus the risk of being killed where risk of death per hour, r_d, is a function of government enforcement efforts, G, multiplied by the hours spent poaching, t_p. This equation is subject to both a budget and time constraint (Equations 2 and 3 respectively).

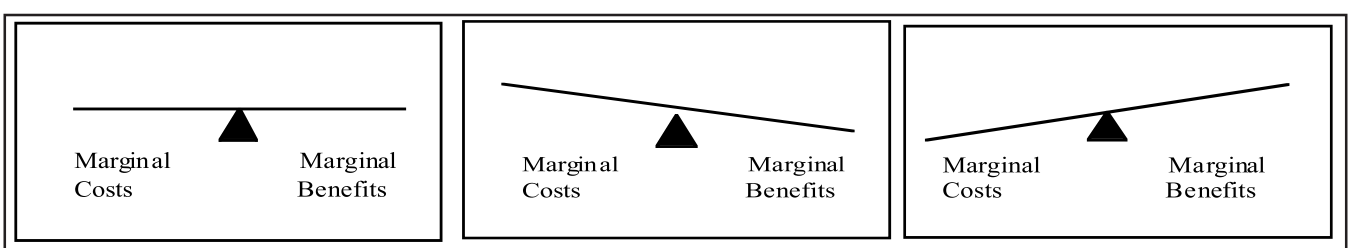
Equation 2.
The budget constraint includes the value of wage labor, w, the hours worked, t_w, the number of elephants, E, and rhinos, R, killed as functions of the hours spent poaching (hunting for elephants and rhinos often occurs simultaneously); unearned income, S; the risk of a fine per hour, r_f, as a function of government enforcement effort; the amount of fine, F; and total consumption, C.

Equation 3.
The time constraint, T, is the number of hours spent poaching plus the hours spent working for a wage.

Equation 4.
Solving these equations using the first order conditions, results in the following equation, which models the decision making process for the time spent poaching.

The left-hand side of the equation represents the marginal costs to the poacher while the right-hand side represents the marginal benefits. The poacher's value of life is represented by $\frac{1}{1 - r_d(G) \times t_p} \times \frac{U(C)}{U'(C)}$, which is multiplied by the risk of death per hour, $r_d(G)$. This value is added to the wage rate per hour and the risk of a fine per hour multiplied by the amount of the fine. A fine could include the cost of imprisonment.

Since this equation is equal on



(i) Equilibrium (ii) Marginal Benefits > Marginal Costs (iii) Marginal Costs > Marginal Benefits

Figure 2. Representation of poacher's decision-making process

the margins, meaning that, at equilibrium, the marginal costs are equal to the marginal benefits. A balanced scale can represent this equilibrium (Figure 2, i). It follows that changes in a number of the variables would influence the poacher to reduce the hours spent poaching, t_p , thus returning the equation to equilibrium. For example, decreases in the price for elephant tusks or rhino horns would lower t_p. Similarly, t_p would be expected to decrease with increases in the risk of death per hour, r_d, the risk of fine per hour, r_f, the amount of fine, F, the non-poaching wage rate, w, or the government expenditures on enforcement, G.

By looking at Equation 4, we can also see the potential disequilibrium in situations with low non-poaching wage rates. In cases where "shoot first" policies do not exist, marginal benefits probably are consistently greater than the marginal costs (Figure 2, ii). This is a likely scenario as even the costs of fines and imprisonment, F, are ultimately limited by the low non-poaching wage rate.

To achieve the conservation objective of having no poaching of elephants and rhinos, the marginal costs of poaching need to be consistently greater than the marginal benefits (Figure 2, iii). Given the difficulty of raising the non-poaching wage rate in a short time period, another option is to raise the marginal costs to the poacher by including the potential of death, represented by the value of a statistical life.

Equation 5.

The expected utility model can be easily extended to include the effects of corruption on the decision-making of poachers. By assuming that a bribe, B, from a poacher makes the risk of detection equal to zero, then Equation 5 follows from analysis at the margin.

In this case, neither the time spent poaching, t_p, nor risk of detection as a function of government expenditures, $r_d(G)$ and $r_f(G)$, are even involved in the equation. The expected benefits from poaching are compared only to the non-poaching wage rate and the cost of the bribe. In addition, we know that the maximum bribe would be equal to the expected costs of enforcement.

Examination of assumptions and variables

When considering this model, it is important to note the underlying assumptions and examine the key variables. First, the model presumes that a poacher receives no utility from death. In other words, a poacher does not place an inherent value in death (such as heaven or hell) or has a bequest value in death. Second, the model does not incorporate the possible negative psychological costs from breaking a law. Psychologists and economists have found that breaking social norms can be perceived as a cost, especially when the law is sustained by social approval or initiated by communal action, such as a vote (Alm et al. 1999). However, it is questionable whether poachers perceive that the anti-poaching laws are sustained by social approval or were established by a vote of their peers. In fact, a significant amount of the poaching activity occurs across national borders, such as Somalian gangs poaching in Kenya or Zambians poaching in neighboring Zimbabwe. Consequently, the psychological penalty is also assumed to be zero.

This model also does not discriminate between "local" and "organized" poaches as described by Bilner-Gulland and Leader-Williams (1992). They describe local poachers as those who go out hunting in pairs on a daily basis. Organized poachers, on the other hand, are formed into a party with hunters, carriers, and a leader. In 1985, it was estimated that local hunters had 0.05 elephant kills and 0.02 rhino kills per expedition, while organized groups had 3.54 elephant kills and 0.15 rhino kills per expedition.

Several studies have estimated the value of a statistical life (VSL) using several different theoretical and econometric techniques. Traditionally, these studies have looked at the correlation between job risk and wage rates and have estimated the statistical value of a life based on the change in wages as job risks increase (holding all other factors constant). Other studies have focused on the expenditures on safety devices. These derived values are frequently used in evaluating the benefits and costs of various public health programs and policies. The majority of these studies have shown that the VSL for a person in the United States is between $3-7 million dollars (Viscusi 1997). However, few, if any studies considered the VSL values for people in developing countries, such as the African countries facing problems with poaching. A critical component of VSL estimates is an individual's expected lifetime wealth, which is derived primarily from current annual income. Consequently, the values for children or the elderly tend to be significantly lower than employed adults. Similarly, the estimates for a poor or unemployed person in a developing country could lead to values considerably smaller than the estimates for the United States.

Some economists have argued that this model is limited and suggest that in addition to lifetime wealth a universal constant for human life should be included in VSL estimates

(Cropper and Freeman 1991). A potential VSL equation that includes this type of universal constant is $VSL = 2(W + C)$, where W is lifetime wealth and C is the constant.

Consequently, a poor person with no annual income and little lifetime wealth could still have a VSL between $1.5 and $3.5 million dollars. When VSL estimates of this magnitude are included in the theoretical model, it becomes apparent that people are unlikely to poach even in situations where the risk of detection is relatively small.

A factor that is not included in the model is the probability of the poacher dying from other causes. This may be especially important in highly impoverished areas where the probability of death from starvation or disease (without the money gained from poaching) may be higher than the probability of death from poaching. In this case, it would still be rational for a person to poach despite the "shoot first" policy.

The estimation of the risk of death or fine is also a key variable in this model. Studies have estimated the probability of a poacher being detected, caught, and successfully prosecuted as between zero and five percent (Bulte and van Kooten 1999). Miliken et al. (1993) estimated the probability of a poacher being killed in Zimbabwae if detected to be 16 percent. An important question is the perceived and real probability of detection. Psychologists and economists have shown that humans tend to overestimate low probability events (Machina 1983; Kahneman and Tversky 1979; Alm et al. 1992). Consequently, a poacher's estimation of his/her risk of detection may not be much different if the odds of detection were either 1 percent or 0.01 percent, yet in reality the consequences for a poacher's expected utility and the governments required expenditures would be quite different. Importantly, the overestimation of low probability events may help reduce the number of poachers killed for the same level of anti-poaching protection.

Implications

The theoretical model of the poacher's dilemma implies that policies that increase the costs or decrease the benefits of poaching will decrease the time a poacher's spends hunting. If the conservation objective is to stop all poaching, then the model suggest that a strict enforcement policy has the best chance of achieving the objective. By dramatically increasing the costs of poaching by including the possibility of death, it becomes irrational for an individual to choose to spend any hours poaching, even with high prices for elephant tusks and rhino horns. Consequently, the populations of elephants and rhinos in protected areas have a chance for recovery. These policies could allow a country, such as Zimbabwe that has excess elephants, to support conservation efforts through the proceeds from selective ivory sales or tourist-oriented hunting expeditions.

A key question is whether local governments have the financial resources to enforce strict anti-poaching policies and whether the anti-poaching units can be free of corruption. The cost of effective anti-poaching enforcement has been estimated as $200 per km^2 (Leader-Williams 1993). It is unclear, however, whether that estimate assumes implementation of a "shoot first" policy. Nevertheless, initiating a "shoot first" policy likely increases the risk of death to members of the government's anti-poaching units, especially in areas where the poachers are highly organized and well-armed. Equipping anti-poaching units with enough firepower to combat these groups may be expensive and hard to sustain. For example, between 1989 and 1994, when Dr. Richard Leakey was Director of the Kenyan Wildlife Service, he raised more than $153 million arming anti-poaching units with airplanes, helicopters, 250 vehicles, and rebuilding the park infrastructure. By 1998, however, the program did not have enough money to keep the aircraft and helicopters properly maintained (Woods 1999). Regardless of the strictness of the anti-poaching policies or the amount of money spent on weapons, efforts must be made to keep the anti-poaching units free of corruption. This can include significantly raising the wages of unit members.

Finally, the ethical and political implications of a "shoot first" policy need to be considered. Placing the lives of wildlife, even charismatic ones such as elephants and rhinos, ahead of the lives of humans would be considered unethical by all humanistic philosophies, such as egalitarianism, libertarianism, and utilitarianism. These philosophies do not grant "rights" or "standing" to non-human entities, such as elephants or rhinos. In contrast, naturalistic philosophies do grant "standing" to non-human entities. While naturalistic philosophies might not assign equivalent values to a human and an elephant or rhino, the tremendous levels of poaching of elephants and rhinos that occurred in the 1970s and 1980s may make "shoot first" policies ethical in terms of naturalistic philosophies (see Kneese and Schulze 1985 for a more thorough discussion).

Whether donor nations would support broad-scale implementation of "shoot first" policies remains to be seen. While it seems likely that these policies would immediately offend donors, the success of fundraising by

Richard Leakey in Kenya, not to mention the successes in Zimbabwae and Nepal, and the lack of international criticism of his program makes the international reaction difficult to predict.

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