Research Focus

How does poaching affect the size of national parks?

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A variety of human activities have detrimental impacts on populations of species the park is designed to protect. These impacts range from direct hunting for trophy or subsistence needs, through vehicular collisions, to the direct loss of habitat due to forestry and agricultural activity. These impacts reduce the effective size of the parks and require changes in management policy that deal both with the direct cause of the problem and the underlying social conflicts that the presence of parks can place on humans in the surrounding communities. Recent studies from the Serengeti illustrate that increases in anti-poaching patrols increase the risk of poacher detection and lead to dramatic declines in levels of poaching. The economic arguments that support investment in anti-poaching patrols, rather than increased sentences for poachers who are caught, can be generalized to examine the costs and benefits of other changes in natural resource management that arise when attempting to manage the impact of anthropogenic activities in and around national parks.

Introduction

A recent paper by Hilborn and colleagues [1] documents huge changes over the last 50 years in the intensity of poaching in the Serengeti National Park, Tanzania. The Serengeti was specifically created to protect the large herds of migratory wildebeest that follow the annual cycle of grass production around the park [2,3]. When the park was first established, the principal job of the park warden was to organize anti-poaching patrols [4]. In the mid-1980s, a diversity of economic crises led to an epidemic of poaching, initially for elephant tusks and rhino horns as the price of these escalated on the illegal commodities market. This drove rhinos to local extinction and severely reduced the elephant population. At the same time, other poachers turned to wildebeest and buffalo as sources of meat for human consumption [5]. The estimates by Hilborn *et al.* ([1]; discussed further in [6]) suggest that the probability of being caught as a poacher declined to around 1% in the mid-1980s; enhanced funding for poaching has now raised this to around 10%. The study illustrates just how fragile national parks are to poaching, particularly if surrounded by a hungry human population that receives limited, or no benefits, from the presence of the park.

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At first glance, the Serengeti study echoes a characteristic pithy and insightful aside in a talk the fisheries biologist Geoff Kirkwood gave 5 days before his unexpected death in the spring of 2006: ‘Of course if we really want to know the effective size of a marine reserve, then we have to multiply its area by the probability that a rogue fisherman will be caught and punished if he poaches in the reserve’ [7]. If there is only a 50% chance of capture and prosecution, then in some ways the park is only half its measured size. There is some exaggeration in this statement, as Geoff well knew, but it provides an important insight that, although perhaps overstating the case, should certainly make us think more deeply about the impact of poaching and other forms of excess mortality on terrestrial parks and marine reserves. For example, if we applied this logic to the 25 000 km^2 of the Serengeti National Park, Kirkwood’s insight implies that it was effectively reduced to 250 km^2 in the early 1980s; the rest was essentially used as an open-access resource by poachers. In the last 10 years, anti-poaching patrols have been increased and alternative sources of food and employment developed for local communities that live around the park, so the Serengeti is effectively now operating at a much higher percentage of its true size. However, Kirkwood’s deeper insights and the study by Hilborn *et al.* sharply illustrates that investments in anti-poaching patrols reduce levels of poaching and allow natural populations to recover.

Of course, there are a variety of details that might modify Kirkwood’s calculation: why should we only consider poachers of specific resources? Should we differentiate local subsistence hunters from professional ivory and rhinoceros horn poachers who hunt luxury items and operate for international syndicates? Indeed, local subsistence hunters might be from cultures that have used game meat for millennia and might resent the presence of the park as a constraint on their land use that benefits wealthy tourists but does not help feed their children. We should also consider nonlinearities in the relationship between the probabilities of capture and park area, for both poachers and anti-poaching patrols. For example, would this calculation be as valid in a small park as in a large park, where edge effects and loss of species with large area requirements interact in complex ways with the impacts of poaching? Moreover, how do we calculate the probability of capture for parks in different parts of the world where the efficacy of law enforcement and punishment might modify the trade-offs between incentive to poach and cost to future livelihood and life expectancy if caught?

A series of earlier papers by E.J. Milner-Gulland and Nigel Leader-Williams used theoretical work based on economic studies of ‘crime and punishment’ [8,9] to examine the cost-benefit analysis of poaching for rhino and elephant in the Luangwa Valley, Zambia [10,11].

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Box 1. The relationship between stock-yield curves and the costs and benefits of legal and illegal exploitation

Most introductory ecology and conservation biology texts include a chapter on harvesting fish populations; here we step beyond this and illustrate the response of the exploited population to the economic supply and demand curve that determines the economic decisions of those exploiting the resource. Milner-Gulland and Mace [22] provide a cogent introduction to this area and eloquently distill key features of the economic theory behind it [8,9,23,24]. Figure I, right illustrates the traditional population ecologist's view of a 'stock–recruitment' relationship; Figure I, left illustrates how economists couple their world to this view of natural resource management. Ecologists are mainly concerned with the relationship between population size and yield; thus, in the absence of exploitation, the population is assumed to settle to a carrying capacity, K. When the population is exploited, the yield first increases to a maximum (MSY, the maximum sustainable yield at roughly half the carrying capacity; this assumes recruitment is of logistic form). Increased levels of exploitation then produce lower yields, as the stock from which the population has been harvested is reduced to lower levels. Economists add the relationship between yield (or demand) and price to this relationship (left); the orange and red curves illustrate the relationship between yield (demand) and price for two different extreme discount rates; the blue lines illustrate the relationship between supply and price.

First, let us consider the yield-price curves: these correspond to different levels of ownership of the resource and reflect different degrees of interest in its long-term viability. Leader-Williams [25] suggests three different approaches to property ownership that apply to natural resources: (1) *private-property* regimes are ones that seek to impose limits on levels of exploitation so that yields are sustained from year to year. From an economist's perspective, this means that future discounts are zero; tomorrow's income is as important as today's. This corresponds to the orange curve in the figure: prices first rise slowly as the yield increases until MSY is reached; prices can then fluctuate, but the yield remains unchanged. This effectively requires levels of self-control that can only be achieved by individuals with a total monopoly, or communities that exhibit huge levels of self-policing. (2) At the opposite extreme is the *open-access* resource (red curve); here the resource is not owned by anyone, and individuals seek to maximize their current profits and have no regard for future opportunities; their disregard for the future means discount rates are infinite. Here the 'tragedy of the commons' [26,27] usually leads to overexploitation and the collapse of the natural resource [28]. This occurs as increased prices lead to increased demand as the resource becomes rarer; ultimately, increased prices can drive exploitation to extinction. (3) Intermediate to these two extremes are *common-property regimes*: these occur when the resources are not privately owned but an identifiable group sets collective rules for how the resources can be used. The yield-price curve for these resources falls between the other two curves and their shape is essentially determined by the discounting rate; if this is relatively short term (for example, if determined by electoral cycles), then it will be closer to the infinite discount model that usually leads to overexploitation; as the group take a longer-term perspective on the value of natural resources, as occurs with cultural icons or religious sites, then the curve more closely approaches the zero discount curve.

The blue lines illustrate the 'elasticity' between demand and price; the steeper (light blue) curves are said to be elastic: a small change in price leads to a large change in demand. By contrast, the darker curves are said to be inelastic: a small change in price leads to a small change in demand. If resources can readily be substituted, then demand is said to be elastic; for example, if poachers can substitute wild buffalo meat for beef, then the price of game meat will be elastic, and consumers will switch to another resource if prices increase. Under these circumstances, the population will tend to be managed at low levels of exploitation that maintain it above the MSY level. In contrast, resources such as ivory, or more generally land, are not substitutable; they are inelastic and this creates the central problem of conservation biology; competition for land use. This is highly inelastic and, unless managed with draconian force, it becomes rapidly overexploited and the increased price that follows from reduced availability creates a spiraling decline of the resource to extinction. Unfortunately, most economists explicitly assume that human ingenuity always leads to the development of alternatives that increase elasticity and that this makes goods readily substitutable as cheaper alternatives are developed. Unfortunately, this has not yet proved to be the case for land, which once clear-cut and converted to agriculture, golf courses or shopping precincts cannot be readily substituted as a resource for most other species. The central problem here is that natural resources tend to do the opposite of consumer resources; consumer resources are usually initially rare and highly prized, human ingenuity then ensures that they become common and competitively priced. In contrast, natural resources are initially common and undervalued; overexploitation and competitive greed then ensure they rapidly become rare, and they are often inherently non-substitutable. Ultimately, increased pressure on land use pushes demand from elastic to inelastic curves (the opposite of that which occurs with consumer resources); this can lead to sudden instabilities in the relationship between demand and yield, which lead to the total overexploitation and loss of the natural resource, particularly when matched by the sudden price surges that often accompany civil unrest.

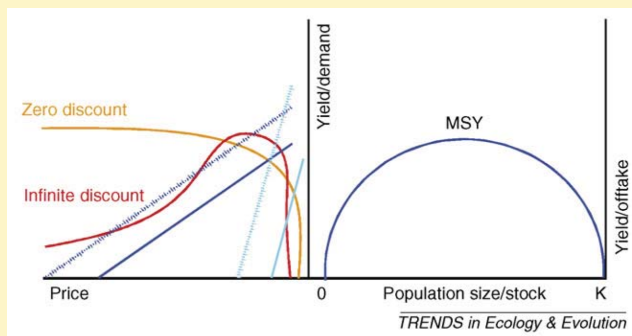

Figure I. The two figures illustrate the relationships between stock and yield as perceived by an ecologist, or natural resource manager (right curve). The figure on the left illustrates the relationship between price and demand (yield) in a form commonly used by economists. The curves share a common (vertical) access that reflects the yield removed from the population; the economist assumes that this yield exactly matches demand, which in turn is a function of price. The price can be determined by social factors that determine rates at which the future value of resources is discounted (yellow and red curves). The price will also be determined by the elasticity of the resource, a measure of how readily alternative resources can be substituted for the resource (dark and pale blue lines).

The paper by Hilborn and colleagues provides an important test of these ideas. At their core is the notion that poaching prevention is more dependent upon high rates of detection of offenders rather than upon the passing of increasingly harsher sentences on those who are caught. Like many problems in economics, the logic of this arises from cost-benefit analyses and assumptions about rates at which people discount the future. Thus, longer prison sentences are discounted heavily in countries where life expectancy is short; by contrast, if rates of detection are high, poachers are constantly looking over their shoulders, as instant loss of current income presents a more immediate threat (see Box 1). The evidence from the long-term study in the Serengeti suggests that funds spent on anti-poaching patrols do lead to dramatic declines in poaching. It also helps change the perspective on the debate about how effective parks are in protecting wildlife while also supplying livelihoods to the people who live around them, and might once have lived within them.

Incidental versus direct poaching

Once we have differentiated between professional and subsistence poaching, we create the potential to recognize other incidental forms of poaching that also have a significant impact on the viability of plant and animal populations in national parks. One extreme example of incidental poaching occurs in Banff and Jasper National Parks, Canada, where there is effectively no poaching, nonetheless, significant numbers of bears, ungulates (such as moose and deer), coyotes and smaller animals such as hares, martens and squirrel are killed or injured in collisions on the transcontinental highway and on the railroad lines that run through the park spilling grain that attracts both ungulates and carnivores that feed on their carcasses once they have been struck by trains [12–14]. In the case of large carnivores, many are also killed as a result of conflicts with humans sharing the key feeding or migration corridors with residents, or recreators, who compete for use of these spaces for hiking, dog walking and mountain biking.

Animal deaths that result from vehicular impacts, or by association with recreational land users, have the same demographic impact as poaching, but it is harder to calculate a ‘probability of capture’ for poachers in these parks. For example, most vehicles travel well beyond the posted speed limit of 70–90 km/h, yet speed enforcement is rarely seen, and some believe that park and provincial officials are actually discouraged from issuing speeding tickets to rushing tourists or long-distance truck drivers. From the most naïve perspective, this effectively reduces the park's size to zero – no one gets caught for accidentally ‘poaching’ the game with the fenders of their vehicles. This creates a significant ‘knock-on’ externality to Canada's booming ‘just-in-time’ delivery service. The catch is that it is the bears, wolves and elk that take the knocks; and they often prove fatal. One partial solution has been the construction of overpasses and underpasses for game to cross the highway [15]. These are used by wildlife [16], but create movement bottlenecks across areas of habitat, particularly when these do not necessarily reflect the intersections of the territories of the carnivores and ungulates that use them. Ironically, the initial resistance to the construction of these corridors was only overcome when the safety benefits to humans were emphasized – they would reduce the human fatalities when speeding humans collide with deer blinded in their headlights [17].

These cost-benefit analyses will ultimately determine whether tourists will eventually only have mountains of ‘rock and ice,’ and each other, to view in Jasper National Park; and sightings of bear, wolves and elk will be restricted to old postcards. The simplest solutions would be to limit recreational use and further reduce the demand for multiple land use by raising the highway and railroad onto viaducts that run above the ground – game could then disperse beneath this; potentially, the rain of grain from the ancient train carts would now actually help sustain recovery in the game populations. This would allow Canada and the world's wealthiest province to demonstrate that it is solidly committed to conserving its natural wealth. It would also allow Canada to demonstrate that its engineering prowess equals that of nations that have recently completed construction of new road and rail viaducts that eloquently complement the already spectacular landscapes of the wild areas they pass through (Figure 1). The construction of road and rail viaducts provides important testimony to France's and even China's [18] commitment to having both a booming economy and viable populations of non-voting species; Canada and other nations should follow suite!

Tragically, a diversity of similar incursions effectively diminish the size of many of the world's national parks; the successes observed in the Serengeti by Hilborn and colleagues contrast with epidemics of poaching of wildlife and land in other places: farms and illegal logging camps are easily visible during overflights of Bukit Barisan National Park in Sumatra, Indonesia [19]; the water supply of the Masai Mara Game Park in Kenya is increasingly diverted for agriculture before it reaches the park – this will again threaten the dry season habitat of the Serengeti wildebeest [20]; and invasive species in most of the world's parks effectively poach habitat away from native plants and animals. In both the Mara and Serengeti, tourist minibus drivers, perpetually optimistic for large tips from their clients, increasingly harass wildlife, particularly large carnivores; this creates a classic tragedy of the commons which reduces the quality of everyone's safari.

The paper by Hilborn *et al.* [1] and Geoff Kirkwood's casual aside provides important insights that have to be

Figure 1. Norman Foster's viaduct across the Millau Valley in the Languedoc region of France.

considered when we initially congratulate ourselves on setting aside a global park network that is roughly equivalent in area to the Indian subcontinent [21]. Until we can truly enforce measures that increase detection of deliberate and incidental poaching of wild animals and plants within national parks and protected areas, then the bank account of future biological wealth might be considerably less secure than we currently assume. Moreover, this increase in protection has to be undertaken while providing viable alternative livelihoods and benefits to the people who used to live in the areas now occupied by national parks; many are now excluded from using them in their traditional ways, and the resentment they feel is a further incentive to illegally poach and farm.

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