Ecological Modelling 337 (2016) 73–78

Contents lists available at ScienceDirect

Ecological Modelling

journal homepage: www.elsevier.com/locate/ecolmodel

Devaluing rhino horns as a theoretical game

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ARTICLE INFO

Article history:
Received 1 March 2016
Received in revised form 14 June 2016
Accepted 15 June 2016

Keywords:
Ceratotherium
Diceros
Game theory
Poaching
Rhinoceros
Wildlife management

ABSTRACT

The poaching of rhinos has increased dramatically in recent years, creating an ongoing problem and cost to rhino managers. A manager may decrease the reward to the poacher by devaluing the horn such as dehorning so that only a stub is left, or inserting a poison, dye or GPS tracker. However, as it is impossible to remove all value of the horn (a stub remains, poison fades, or GPS trackers can be removed) a poacher may still kill the rhino for the partial gain from the horn, and to avoid tracking this particular rhino in the future. We consider the problem as a theoretical game, where the players are poachers and a rhino manager. By considering the payoff to both manger and poachers we highlight the manager's struggle to discourage poachers to not kill a devalued rhino, despite the loss of time, and increase of risk, to the poacher. Generally, the manager can only influence the situation if virtually all rhino horns are devalued, or the risk involved to the poacher is increased, such as through greater enforcement. However, the cost to devalue the last few rhinos may be very costly due to the sparsity of rhinos, and the rhino manager can easily make a loss by trying to devalue the last, few rhinos. But, whilst a few rhinos remain with their intact horn, a poacher is unlikely to avoid a particular ranch.

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1. Introduction

The illegal trade in rhino horn supports aggressive poaching syndicates and a black market (Nowell et al., 1992). This lucrative market entices people to invest their time and energy to gain a 'winfall' in the form of a rhino horn, through the poaching of rhinos. In recent years poaching has escalated to an unpresidented level resulting in concerns over their future existence (Smith et al., 2013). In response, rhino conservation has seen increased militarisation with 'boots on the ground' and 'eyes in the sky' (Duffy et al., 2015). An alternative method is to devalue the horn itself, one of the main methods being the removal so that only a stub is left. The first attempt at large-scale rhino dehorning as an anti-poaching measure was in Damordond, Namibia, in 1989 (Milner-Gulland and Leader-Williams, 1992). Other methods of devaluing the horn that have been suggested include the insertion of poisons, dyes or GPS trackers (Gill, 2010; Smith, 2013). However, like dehorning, they cannot remove all the potential gain from an intact horn (poison and dyes fade or GPS trackers can be removed). This paper considers the general strategy of devaluing horns, which includes dehorning.

Rhino populations now persist largely in protected areas or on private land, and require intensive protection (Ferreira et al., 2014). For wildlife manages law enforcement is often one of the main methods of detering poaching, however rhino managers can remove the poaching incentive by devaluing their rhinos (Milner-Gulland, 1999).

A manager does not need to choose law enforcement or devaluing, but perhaps adopt a combination of the two; especially given that devaluing rhinos comes at a cost to the manager, and the process comes with a risk to the rhinos. Milner-Gulland and Leader-Williams (1992) found the optimum proportion to dehorn using mean horn length as a measure of the proportion of rhinos dehorned. They showed, with realistic parameter values, that the optimal strategy is to dehorn as many rhinos as possible. Further, Milner-Gulland and Leader-Williams (1992) discussed dehorning as a better strategy than anti-poaching protection since the benefits are carried over to subsequent years where the rhino horn length is shorter, whereas anti-poaching protection costs are renewed each year.

We consider one year only, for a single rhino manager. We assume a given amount of resource available for the year, and that all rhinos initially have intact horns. Rhino managers may devalue a proportion of their rhinos. We assume that managers would like to devalue as few as possible, whilst still ensuring the safety of their rhinos. This is a problem of conflicting interests where game theory can provide an appropriate framework. A game theoretic perspective provides insights about (a) the strategies different stakeholders will likely adopt given their objectives when consensus,

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http://dx.doi.org/10.1016/j.ecolmodel.2016.06.009
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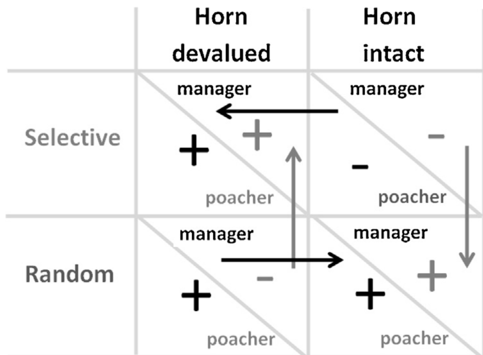

Fig. 1. The dynamic between rhino managers and poachers. The arrows indicate the direction that either the manager (black) or poacher (grey) would move to minimise loss. For example, if poachers are selective, the manager would choose to devalue rhino horns.

compromise, or cooperation are feasible, (b) what types of cooperation best reflect stakeholders interests and achieve their objectives (c) which stakeholders are likely to form coalitions, (d) the range of possible outcomes under non-cooperative and cooperative decision-making dynamics, and (e) whether an optimal or satisfactory solution for all stakeholders can be reached simultaneously (Colyvan et al., 2011).

The model we present is similar to the cyclic model used by Bell (1986), where the stakeholders were insects and flowers. Insects and flowers each behaved in one of two ways determined by particular rules, and a cycle of behaviour was formed. With rhino managers and poachers the rules engender a different, non-cyclic, pattern of behaviour where the system settles to one of two states.

Poachers may either only kill rhinos with full horns, 'selective poachers', or kill all rhinos they encounter, 'random poachers'. If all rhinos are left by the rhino manager with their intact horns, it does not pay poachers to be selective so they will become random poachers. Conversely, if all poachers are selective, it pays rhino managers to invest in devaluing his/her rhinos. This dynamic is represented in Fig. 1.

Assuming poachers and managers will always behave so as to maximise their payoff, there are two equilibriums: either all devalued and all poachers selective; or all horns intact and all poachers random. Essentially, either the managers win, the top left quadrant of Fig. 1, or the poachers win, the bottom right quadrant of Fig. 1.

2. The model

Consider the situation on one ranch. Let r be the proportion of devalued rhinos (where here, rhino value is only measured by its horn value), and s be the proportion of selective poachers. Assuming a poacher encounters a rhino, there are four scenarios which depend on the strategy of the players. The probabilities of each of these four scenarios are given in Table 1.

The actual probabilities in Table 1 are unknown to the players. They must choose which strategy to take with imperfect information. Poachers can choose their strategy instantaneously, unlike the manager. Furthermore, at any time, the manager can only choose to either not devalue any further rhinos, or to increase the proportion which are devalued.

Table 1
The probabilities of each of the four scenarios given that a poacher has encountered a rhino.

	Horn devalued	Horn intact
Selective	rs	$(1-r)s$
Random	$r(1-s)$	$(1-r)(1-s)$

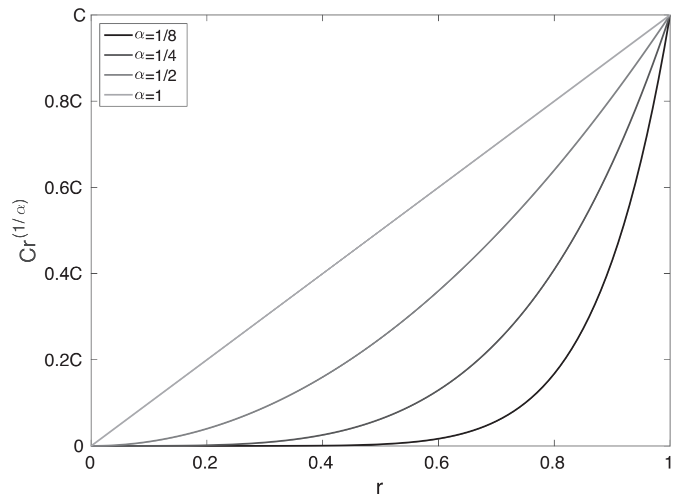

Fig. 2. The cost to devalue the proportion r of the rhinos for varying α. The cost to devalue all rhinos ($r=1$) is C.

2.1. The rhino manager

The rhino manager initially has C resources, which is the cost to devalue the horns from all of his/her rhinos. Then the cost to devalue a proportion of the rhinos is $Cr^{1/\alpha}$, $\alpha>0$. When $\alpha=1$ the cost to devalue the first rhino is the same as devaluing the last rhino, the relationship is linear. This would represent a high density of rhinos where there is no time penalty incurred to find each rhino. However if the cost to devalue the last few rhinos is more costly because of the time needed to find the last remaining intact rhinos (Milner-Gulland, 1999), then $0<\alpha\le 1$, see Fig. 2. As $\alpha\to 0$ the marginal cost to devalue the last few rhinos tends to infinity, representing the difficulty of tracking very sparse rhinos. Note that if devaluing the first rhino is the most expensive, perhaps due to start-up costs, then $\alpha>1$, however in reality this is unlikely to be the case so we consider $0<\alpha\le 1$ only.

Let K be the cost to the rhino manager from rhino killings. Then the expected payoff for a manager under each scenario is given in Table 2, where the payoff is in terms of reducing the loss to C. Therefore, the expected payoff to the manager is the sum of all four expected payoffs in Table 2,

$$E_m = r(sK - Cr^{1/\alpha}). \tag{1}$$

Notice that when $r^{1/\alpha} < sK/C$ the expected payoff is positive, which signifies the savings from unused resources C.

The expected payoff to the manager is linear in s, meaning that for any given proportion of devalued rhinos r, the relationship between the proportion of selective poachers s and the expected payoff to the manager is linear. Therefore for any given r, if there is a maximum expected payoff to the manager, it is at $s=1$ (all rhino horns are devalued).

Conversely for a varying proportion of selecting poachers s, the expected payoff to the manager is at a maximum when

$$r = \left(\frac{\alpha s K}{C}\right)^{\alpha/(\alpha-1)}, \tag{2}$$

Table 2
Expected payoff to the rhino manager under each scenario.

	Horn devalued	Horn intact
Selective	$-Cr^{(\alpha+1)/\alpha}s$	$-K(1-r)s$
Random	$-(K+Cr^{1/\alpha})r(1-s)$	$-K(1-r)(1-s)$

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